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ORIGINAL ARTICLES.

The Petrology and Structure of the Charnian Rocks of Bardon Hill.

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1. Introduction.

THE geology of Charnwood Forest has engaged the attention of so many eminent investigators in the past that its problems have become both attractive and intricate.

Residing within easy reach of the area, the author has become familiar with the district as a whole, and with the details which make up the smaller district of which the centre is Bardon Hill.

It is with great diffidence that he ventures to put into print some of the results of his field and laboratory investigations.

Charnian rock-names are peculiar to themselves; unless the reader has field or hand specimen knowledge of the rocks, the terms in vogue will convey but little conception of local petrology. It is, however, difficult to improve on those sanctioned by usage, and in the following paper, no new ones will be introduced. To clear the ground the principal types exposed at Bardon Hill will be defined.

1. *Peldar Porphyroid.*—A quartz-porphyrite; the type rock is exposed at Peldar Tor, nearly 2 miles north of Bardon Hill.

2. *Purple Porphyroid.*—A porphyrite; it differs from the last named in containing smaller felspar phenocrysts and in having little or no quartz.

3. *Bardon Breccia.*—A rock variously interpreted as a volcanic agglomerate or a breccia. The author regards it as an intrusion breccia.

4. *Bardon Good Rock.*—A quarryman's term adopted by Bonney which is convenient for describing the homogeneous rock which occurs as patches and bands in the Bardon Breccia.

5. *Slate Agglomerate.*—A lithic tuff marking a horizon in Charnian Rocks. It consists of slate-coloured fragments of variable coarseness.

6. *Hornstone.*—A fine-grained rock of greenish colour that is (at Bardon Hill) closely associated with the Slate Agglomerate.

2. PREVIOUS WORK ON BARDON HILL ROCKS.

1. *Q.J.G.S.*, Nov., 1877, May, 1878, Aug., 1880, and vol. xlvii, 1891 (Bonney and Hill).
2. GEOLOGICAL MAGAZINE, Dec. VI, Vol. II, No. 618, 1915 (Bonney).
3. *Geological Survey Memoir to Sheet* 155, 1900 (Watts).
4. *British Assoc. Handbook*, 1907 (Leicester) (Watts).
5. *Trans. Leicester Lit. and Phil. Soc.*, 1907 (Stracey).
6. *Trans. Leicester Lit. and Phil. Soc.*, 1915 (Bennett).

A brief survey of the above work is of value here:—

Bonney and Hill after first postulating a non-igneous origin for the Charnian Rocks of Bardon Hill establish in a later paper that the rock exposed both at Peldar Tor and Bardon Hill is a lava. In the 1915 paper Bonney suggests that the Good Rock of Bardon Hill is also igneous and that the enclave-crowded rock may be a flow-breccia.

Professor Watts regards the Peldar Porphyroid as an intrusive rock; he cites as evidence of this certain contact phenomena; he classes the bulk of Bardon Hill rocks as coarse agglomerate.

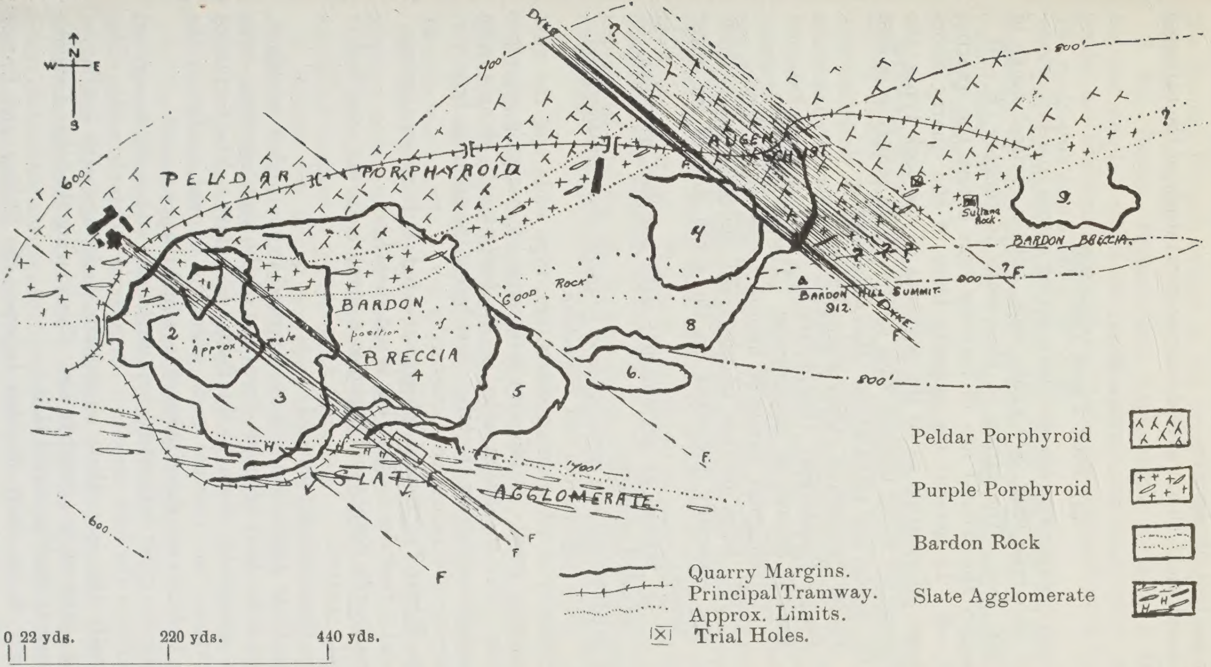
Dr. Stracey advocates the view that the Bardon Good Rock is a lava with abundant enclaves.

Dr. Bennett emphasizes the absence of true contacts between the Peldar Porphyroid and the main Bardon rock.

3. METHODS OF INVESTIGATION.

The investigation involved:—

1. Detailed mapping on a scale of 25 inches to 1 mile.
2. The collection of numerous specimens, special regard being given to frequency of occurrence.



Map of Bardon Hill Quarries, reduced from 25" to 1 mile to about ½ scale. FF, faults, mainly tear faults. 1, Sump Hole. 2, 1st bench. 3, 2nd bench. 4 and 5, 3rd bench. 6, "Scotland." 7, Lower Siberia. 8, Upper Siberia. 9, Extension Quarry.
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3. A careful search of boundaries and of transitional areas for possible contact phenomena.

4. Mineralogical, chemical and microscopical study of the collected material.

FIELD DATA.

(*a*) *Rock Types Described.*

The quarry exposures are excellent, giving access to a belt three-quarters of a mile long, 300 yards wide, with a vertical range of nearly 400 feet. The strike of the rocks is roughly E.—W.; consequently the critical line of traverse runs across the quarries from N.—S. In general the easterly faces of the quarry floors afford most information as to the sequence of the rock types, the floors themselves being masked with debris. This sequence is best seen in the second and third levels. It is as follows :—

1. *Peldar Porphyroid.* (Quartz-porphyrite).
2. *Purple Porphyroid.* (Porphyrite).
3. *Bardon Breccia or Agglomerate.* This includes :—
    (*a*) irregular bands of homogeneous Good Rock;
    (*b*) large patches of presumed andesitic ash: these are especially prevalent on the south side of the lower levels;
    (*c*) breccia or agglomerate with angular, irregular, or rounded enclaves.

These subdivisions are in no sense in sequence but intermingled.

4. *Slate Agglomerate and Hornstone.*

The difficulty of determining where one type ends and the next begins is very great—a difficulty overcome by carrying reference specimens. The succession noted in the lower levels obtains with minor variations high up the hill. Just below the summit, however, the following differences are noteworthy :—

1. The Peldar Porphyroid is highly sheared; it becomes an augen-schist, and it includes a dyke that is not sheared.

2. The Purple Porphyroid occupies a much narrower zone and is also highly sheared.

3. The Breccia is not sheared.

4. The Slate Agglomerate is not exposed in the higher workings. Two trial holes have been put down east of the main quarries—both of them apparently close to the Peldar boundary. The further of these exposes an unusual rock which is known locally as the Sultana Rock, an apt description of its mottled appearance.

Though the types indicated are quite definite and easily recognized their limits in the field are either irregular or indeterminable. This is especially the case where contiguous rocks are very similar in type, e.g., between the porphyroids. Considering the main divisions in sequence it may be stated that :—

1. There is no sharp division between the Peldar and Purple Porphyroids.

2. The latter rock in turn is nowhere distinctly separable from the Bardon Breccia except in the level called Siberia, where the boundary is a fault.

3. The Bardon Breccia-Slate Agglomerate division is distinct but not simple: the latter lies steeply on the main rock; its finer grades are fissile and sheared and there is a suggestion of bedding. The rock simulates a dip of 70° S.W.

4. The Hornstone lies within the Slate Agglomerate and unless repetition by step faulting is assumed, can only be a fine-grained modification of that rock. The largest mass exposed measures but 8 yards across.

(*b*) *Faulting.*

Evidence of local earth-movements is seen at all levels. The strike of the faults observed is nearly constant, their direction being approximately N.W.—S.E. The main faults are indicated on the accompanying map. The lower workings are traversed by a fault-bounded crush zone of about 10 yards width. This zone traverses porphyroids, breccia, and slate-agglomerate; within it the rocks are highly altered and decayed. Other minor crush bands occur.

In the level just below the summit of the hill the quartz-porphyroid appears further south than might be anticipated from its trend in the lower quarries. This fact, considered in relation to its sheared condition and also the narrowing of the purple porphyroid before-mentioned, justifies the fault recorded at this point. The unsheared dyke which occurs here has a direction closely that of the faults.

(*c*) *Contacts.*

Extreme care was taken in the search for, and examination of contacts. The general results are expressed here:—

1. No undeniable contact of the Quartz-porphyroid with the Breccia was found.

2. The Purple Porphyroid which is contiguous with the Breccia displays no indisputable evidence of contact.

3. There are now no features visible capable of interpretation as chilled margins or reddening by intrusion.

4. Neither the Peldar nor the Purple Porphyroid sends tongues or fingers into the Breccia; such fingering might be reasonably expected if the latter at the time of intrusion had been unconsolidated ash. In contrast the insertion of the matrix of the Breccia into its enclaves is notable.

5. The Purple Porphyroid has included several types of fragments, the predominating type being undoubtedly Peldar Porphyroid in origin.

6. The Bardon Breccia contains a still greater variety of enclaves—of these only a few are of Peldar type, though a considerable number are apparently derived from the Purple Porphyroid. The distribution of these fragments calls for special notice and requires explanation. Both the above types, as enclaves in the main

Bardon rock, are found in that part of the rock contiguous to the porphyroid masses.

7. The Porphyroids and the Breccia have each of them a certain amount of included material obtained from a common source. From the foregoing data it is clear that the evidence of contact is subordinate to the evidence of xenoliths, in determining the chronological sequence of the rocks of Bardon Hill.

(*d*) *Evidence of flowage in the rocks.*

1. There is no decipherable orientation of the phenocrysts in the Peldar Porphyroid. The same may be said of its enclaves.

2. The enclaves of Peldar Porphyroid lying in the Purple Porphyroid often show a distinct orientation.

3. Flowage in the Breccia is not conclusively displayed, but in two parts of the quarries parallel arrangement of fragments very suggestive of streaming is to be seen.

4. PETROLOGICAL DESCRIPTIONS OF BARDON HILL ROCKS.

The author has but little to add to the detailed descriptions of Bonney (op. cit.). Owing, partly to the fact that all the rocks concerned are very similar chemically, and partly to the fact that they are much altered, the microscope is of very limited usefulness in solving the nature and field relationship of these rocks. Macroscopic characters become relatively more important; on this account they are given in some detail.

(*a*) *The Porphyroids.*

Peldar Porphyroid (Quartz-porphyrite).—Phenocrysts of pink or grey felspar equant in form and with diameters up to 0·3 inch, together with rounded or sub-angular quartz crystals, are set in a purple or green groundmass. The enclaves of this rock are mostly of a fine-grained character and are either pink or greenish grey in colour. Microscopically the felspar phenocrysts show much alteration, but some are sufficiently fresh to be identified as orthoclase, and others, as approaching oligoclase in composition. Alteration is mainly in the direction of epidotization and chloritization. Secondary quartz and water-clear albite in grains accompany the epidote. The quartz crystals are generally clear; a few show strain effects and fewer display absorption-margins. The groundmass is micro- and crypto-crystalline; much of it is obscure. Granules of epidote, of chlorite and dusky specks of iron ore are everywhere. A little apatite is seen. The texture is felsitic.

There is a distinct analogy in the appearance of the phenocrysts to those of a porphyritic pitchstone, but in one slide only was there any distinct evidence of devitrification, namely a pseudomorph of a microspherulite.

Purple Porphyroid (*porphyrite*).—This rock was mentioned by Bonney, though not recognized by him as a separate unit of the

Bardon complex. It differs from the Peldar type in having smaller and less equant felspars; these are grey or transparent rather than pink. Quartz-phenocrysts are practically absent. The groundmass is purple or dark grey when fresh. Enclaves are numerous, the principal variety being Peldar Porphyroid. Under the microscope the rock is seen to have the same structure as the Peldar Porphyroid. In several slides the felspars were well preserved: both orthoclase and plagioclase are present, the latter in greater amount, and in variety near to andesine. The average linear dimensions are about one-third those of the quartz-porphyrite. The groundmass is felsitic but rather coarser than that of the porphyroid and breccia which lie next to it. Epidote, chlorite and iron ores, as in the Peldar type, cloud the sections.

(*b*) *Bardon Breccia.*

(1) *Good Rock.*—Hand specimens of this rock show a range of colour, but typical specimens are olive or greyish green. When highly epidotized, it is streaked or blotched pink. Quartz-phenocrysts are absent. The felspar individuals are smaller and more lath-shaped than those of the Purple Porphyroid. They are generally clear. Microscopically the rock is much like the porphyroids, but on the whole more altered. Epidotization has advanced so far in some slides as to blur the phenocryst outlines, though the crossing of the nicols reveals them plainly enough. Three sections showed small quartz-phenocrysts, displaying marginal corrosion.

The groundmass is distinctly felsitic. As is noted in the macroscopic description pink areas always correspond to parts where there are concentrations of epidote and limonite. This statement is applicable to the rocks of Bardon Hill generally, and the identification of contact by reddening becomes uncertain on this account.

(2) *Bardon Breccia.*—The matrix of the breccia and the good rock are identical, both microscopically and macroscopically. The enclaves are very varied and highly interesting.

General features—the rock fractures across enclave and matrix giving a strong suggestion of welding by the matrix. The margins of the enclosed fragments show a range from completely digested enclave to enclaves with entire and angular margins. This grading by margin roughly corresponds to a grading by size of the xenoliths. The penetration by the matrix is distinctly seen in many enclaves. No fragment having a length greater than 2 feet was found.

Description of the enclaves.—The bulk of these included fragments are undoubtedly porphyroid in nature. A rough classification used by the author in the field is:—

1. Pink porphyroid.
2. Purple porphyroid.
3. ? Ash.
4. Peldar porphyroid.
5. Chloritized fragments (probably pink porphyroid).

The distribution of these fragments has already received some notice. Enclaves of Peldar Porphyroid are never found far from the outcrop of that rock. The same fact applies, though not so rigidly, to the Purple Porphyroid fragments. Both these types are less common in the Breccia than the Pink type. This latter attains its maximum frequency in the centre of the mass, but is less abundant towards the south margin of the Breccia, where fragments seem to have an ashy character. The pink enclaves, when decipherable, are seen to differ from the porphyroids of the quarries both in the hand-specimen and under the microscope. They are not conspicuously porphyritic, and in several slides the groundmass is hyalopilitic. They recall the rocks of Trilobate Plantation and Grimley.

Microscopically, the relations of the enclaves to the surrounding material are always obscure. What appear in the hand-specimen to be contact rims, resolve themselves by magnification into areas where epidote and limonite have formed more abundantly. Penetration by the matrix is, however, distinctly seen in some slides. It can safely be said that no difference is noticeable between the margins of enclosures in the Peldar Porphyroid and those seen in the Bardon Breccia.

(c) *Minor Petrological Features.*

Sheared Peldar Porphyroid (Augen Schist).—The effect of shearing has been to elongate the felspars averaging 0·25 inches into sericitic fibres 0·45 inches long. The pinkness of the felspars disappears, the iron ores to which it is due possibly contributing to the abundant chlorite. A remarkable feature of the rock is the comparatively low epidote content. This feature probably dates the shearing to a time prior to the general alteration of the main Bardon rocks.

Dyke (*cutting sheared Peldar Porphyroid*).—This rock is lighter in colour than the average Bardon Rock. It is much decayed; two slides of the rock show well-preserved pyroxene outlines, the replacing material being clino-zoisite in part. The occurrence of pyroxene in the main rocks of Bardon Hill is undoubted; in the porphyroids and breccia pseudomorphs of this mineral occur, but only in this dyke are the idiomorphic outlines very pronounced. The dyke has not suffered shearing; in direction, it follows the general faulting.

The Sultana Rock.—This rock has been mentioned previously; it is a mongrel rock, with very strong affinities to the Peldar Porphyroid: its felspars are identical with those of that rock.

(*d*) *General remarks.*

The altered condition of all the above rocks throws on the investigator the onus of making decisions from incomplete, and frequently vague data. The author found it necessary at an early stage of his work to compile criteria to assist him in distinguishing altered tuffs from altered igneous rock. Within limits these criteria proved useful but by no means infallible. A summary of these is now given.

5. CRITERIA OF DISTINCTION BETWEEN ALTERED TUFFS AND ALTERED IGNEOUS ROCKS.

IN TUFFS.	IN IGNEOUS ROCKS.
(a) Phenocrysts.	
1. Broken fragments predominate; good outlines are infrequent or absent.	1. Euhedral or subhedral crystals predominated.
2. Glomeroporphyritic aggregates are common.	2. Crystal margins often show penetration or absorption.
3. They display no sign of orientation, and often appear alien to the groundmass.	3. If broken, fragments are in situ, and can be figuratively assembled.
4. The proportion of phenocrysts to groundmass is often much higher than in igneous rocks of like composition.	4. In any area of moderate extent the proportions of any mineral species are approximately constant.
	5. Occasionally crystal orientation is shown.
	6. Crystals are in optical continuity with the groundmass.
	7. Except where an igneous rock has picked up fragments of a crystal tuff, they are in normal proportion to the groundmass.
(b) Groundmass.	
1. The matrix of a tuff is often made up of broken and whole crystals of the same material as the phenocrysts.	1. The texture may be felsitic or hyalopilitic in character.
2. It varies distinctly in texture and composition in different parts of the specimen.	2. If cryptofelsitic, it is only distinguished with difficulty from finely commuted clastic material.
(c) Enclaves.	
1. These show abrupt boundaries and have a pronounced alien appearance.	1. They are welded to the groundmass, and have in general, vague margins.
2. Their margins are entire, i.e. are not penetrated by the groundmass material.	

6. CHEMICAL AND MINERALOGICAL DATA.

The available analyses of the Bardon Hill rocks are those quoted in the papers of Bonney and Hill. A critical exploration of the figures given, shows these to be of little real value to petrological discussion. They serve to class the range of rocks under discussion as lying between the limits quartz-porphyrite and porphyrite. It is impossible (owing to the advanced state of alteration) to check the analyses by computing mineral content, though by attempting the isolation of epidote using bromoform and methylene iodide the author obtained some interesting results :—

	Peldar Porphyroid. %	*Bardon Good Rock.* %
Sp. Gravity less than 2·9 . .	84·6	76·2
,, ,, 2·9 to 3·3 . .	14·2	22·1
,, ,, above 3·3 . .	0·9	1·1

These figures confirm the microscopic diagnosis of a considerably higher epidote content in Bardon Good Rock. In course of his investigations the author found the carbonate content of the porphyroids and breccia. The figures range from 0·9 per cent. to 1·1 per cent., the Peldar rock giving slightly higher results than the breccia. These results are consistent with the greater epidotization of the latter rock, and also support the prevalent idea that when exposed in Triassic times the rocks were subject to desert conditions. The norms of the Peldar Porphyroid and Bardon Breccia as calculated from the existing analyses are helpful in discussing the petrological identity of the latter. They are given here, and along with them norms calculated for secondaries :—

(*a*) PELDAR PORPHYROID.

Chemical Composition.		*Norm (primaries).*		*Norm (secondaries)*	
SiO_2	71·44	Quartz	42·6	Quartz	44·5
Al_2O_3	10·54				
Fe_2O_3	3·81	Magnetite	5·6	Magnetite	3·4
FeO	2·25	Hypersthene	5·0	Serpentine	8·8
MgO	2·95	Diopside	7·1		
CaO	5·33	Anorthite	17·7	Epidote	23·0
Na_2O	1·93	Albite	16·3	Albite	16·3
K_2O	0·84	Orthoclase	5·0	Orthoclase	5·0

The minerals selected as norm minerals (secondaries) bear some relation to the mode of the rocks. In actuality, limonite should be read for magnetite and chlorite for serpentine, but the soda and potash felspars may be considered as little changed in amount, secondary albite being a prominent mineral.

(*b*) BARDON GOOD ROCK.

Chemical Composition.		*Norm (primaries).*		*Norm (secondaries).*	
SiO_2	59·86	Quartz	18·5	Quartz	22·5
Al_2O_3	16·00				
Fe_2O_3	4·47	Magnetite	6·5	Magnetite	4·6
FeO	3·64	Hypersthene	9·7	Serpentine	12·7
MgO	3·90	Diopside	5·9		
CaO	8·06	Anorthite	28·8	Epidote	33·2
Na_2O	2·60	Albite	22·1	Albite	22·1
K_2O	1·20	Orthoclase	6·6	Orthoclase	6·6

Using the above figures for norm mineral percentages, and taking the following as average specific gravities—quartz, 2·65; orthoclase, 2·55; albite, 2·6; anorthite, 2·76; diopside, 3·3; hypersthene, 3·5; magnetite, 4·5; epidote, 3·3; serpentine, 2·7; the calculated specific gravities for unaltered and altered rocks become :—

(*a*) Peldar Porphyroid, 2·83 and 2·868.
(*b*) Bardon Good Rock, 2·843 and 2·964.

There is not the slightest doubt that the figures given for soda and potash in the Peldar analysis are too low—if these were corrected the calculated gravity would be nearer the figures obtained by experiment. In all probability the same comment holds good in regard to the Good Rock figures although it must be admitted that orthoclase is not so conspicuous as in the porphyroids.

Specific Gravities of the Bardon Hill Rocks.

A large number of determinations were performed, using specimens averaging over one pound in weight, the results are summarized here :—

Peldar Porphyroid (25 samples).
Minimum 2·721 Maximum 2·843 Average 2·748
Purple Porphyroid (18 samples).
Minimum 2·751 Maximum 2·774 Average 2·760
Bardon Good Rock (20 samples).
Minimum 2·799 Maximum 2·874 Average 2·84
Bardon Breccia (Good Rock and Enclaves) (31 samples).
Minimum 2·770 Maximum 2·888 Average 2·808
Slate Agglomerate (6 samples).
Average 2·750

Examining the figures for the Peldar Porphyroid and the Bardon Good Rock it is noticed that the theoretical figures are considerably higher than the actual. Taking into account the errors in the alkali figures, and the fact that there are no figures given for H_2O, or CO_2, TiO_2, etc., the discrepancies are lessened. The tangible results of the discussion are :—

(1) Proof that epidotization, chloritization and other less definable alteration has produced contraction in the rock—a contraction quite sufficient to account for consolidation of a tuff to resemble true igneous rock.

(2) The unlikelihood that Bardon Good Rock could be constructed out of tuff material derived from rocks of composition like Peldar Porphyroid.

(3) The lime content of the Bardon analysis seems to signify a different intrusion, since it cannot be accounted for by infiltration of $CaCO_3$.

It should be further emphasized that the Bardon analysis is absolutely that of an igneous rock.

(4) As of further interest, though of little value to the argument, the fact that both original orthoclase and much secondary albite are seen in these rocks otherwise highly altered, indicates little loss of alkalies when epidotization began. This with convergent field evidence, date the main metamorphism of these rocks to a period not very long after their intrusion.

7. Summary and Conclusions.

It is admitted that the data, from which the author draws his conclusions are, taken piecemeal, scanty, hazy, and often ambiguous. The main purpose of the investigation was to examine the contention of Bonney that the phenomena of Bardon Hill might possibly be explained by assuming flow-brecciation, and also to satisfy the author's own observation of a not irregular distribution of enclaves, which seemed to him to warrant a revision of the ideas held on the relative age of the units, that go to the building of the hill. Perhaps the main quest may be summarized into—whether the Bardon Rock is to be regarded as merely compacted agglomerate or whether it is truly igneous ? With these purposes in view the groups of data given in this paper rank in order of value : 1, Field Data ; 2, Macroscopic Data ; 3, Microscopic Data ; 4, Chemical Data. This order holds good, because the more searching the investigation the more obscure the real issues become—befogged by the increasing insistence of metamorphic phenomena. Any conclusions drawn must satisfactorily explain the bulk phenomena of the Bardon Hill rocks and must depend on converging evidence. Where two opposing explanations are possible, the author has adopted the simpler as the more likely.

(*a*) *Bardon Rock* (*Good Rock and Breccia*) : *What is its Nature ?*

Data in Favour of Compacted Agglomerate.	Data in Favour of Xenolith-Bearing Igneous Rock.
(*a*) *Field Data.*	
1. The rock weathers unevenly, the matrix is less resistant than the assumed fragments.	1. The quarry is massive, its jointing is similar to that of local igneous rock, and there is no suggestion of bedding.
2. It varies in type from fragment-crowded, to fragment-free rock.	2. The rock, on fracture, breaks across enclave and matrix indifferently; this in contrast to the Slate Agglomerate where there is a tendency to break round the fragments. Welding and physical homogeneity is strongly suggested.
3. The fragments show marked diversity in shape, size, and source of origin.	3. The enclosures have a definite distribution within the rock; a significant fact is the abundance of porphyroid enclaves nearest the quarry outcrops of porphyroid, from which there is little doubt they have been derived.
4. The enclosed fragments show little or no evidence of junction lines and contacts.	4. This sorting of the fragments can be adequately explained by postulating an intrusion breccia.
5. Flow phenomena are scanty.	5. Orientation of xenoliths is distinctly observable at two places in the quarries.
6. The difficulty of mapping, i.e. of delimiting the Good Rock, admittedly the most igneous-like portion of the Breccia, lends little support to the idea that it is part of an intrusion or flow which failed to pick up xenoliths.	6. The suggestion of digitation by the Good Rock is strong.
(*b*) *Macroscopical Data.*	
1. Many specimens have an ash-like appearance, and fracture like ash.	1. Xenolithic material, especially in the heart of the exposures, is often auto-brecciated. Large fragments have preserved their outlines; fragments of medium size have lost their sharp edges; small fragments have been extensively assimilated.
	2. The welding phenomena noted above are insistent in the hand-specimens.
	3. Good Rock closely resembles a felsite.

	4. The lithological contrast with recognizable agglomerates of the area is striking.
	5. The included material is fresher than fragments in the local agglomerates.

(c) *Microscopical Data.*

1. Several specimens on the evidence of thin slices, are undeniably tuffs.	1. The microscopical character of the Good Rock is that of a felsite.
2. Metamorphism in the direction of epidotization is more advanced than in the igneous Peldar Porphyroid (which the author regards as the older rock).	2 The felsitic groundmass is a feature of most sections whether homogeneous or breccia.
3. A few specimens mainly from one very restricted location contain andesitic lapilli.	3. The bulk of the crystals are entire; occasionally they show parallelism; more rarely flowage is apparent in the groundmass.
4. Many slides show an abnormal concentration of phenocrysts.	4. Though Bardon Rock sometimes shows an abnormal number of phenocrysts, this feature may also be seen in the igneous Peldar Porphyroid.
5. Glassy material (apparently clastic) is sometimes seen in the groundmass.	5. The outlines of the phenocrysts do not differ essentially from those of the porphyroids.
6. No definite marginal alteration of large fragments is noticeable.	6. Strong contrasts as regards the relation of enclaves to groundmass is presented by this rock on the one hand and the High Tors Farm tuff, the Felsitic Agglomerate, the Bomb Rock on the other.

(d) *Chemical and Mineralogical Data.*

1. The extreme mineral alteration which has taken place is quite sufficient to account for the compacting of the rock.	1. The chemical composition of Good Rock is compatible with that of true igneous rock.
	2. The assumption that a fluid igneous rock less siliceous than the porphyroids has picked up alien fragments gives an adequate explanation to the Sp. Gravity data for this rock.

In the author's opinion the balance of the argument is turned by the macroscopical evidence, which, allied with the chemical, mineralogical and general data supports the hypothesis that this rock represents true igneous material which has disrupted the margins of, and been contaminated by, the abutting porphyroids.

(b) *The Relative Age of the Rock Details of Bardon Hill.*

This question also entails the decision as to whether the Peldar Porphyroid is an extrusive rock (Bonney's view) or an intrusive, as stated by Professor Watts. There seems little doubt that the latter interpretation is correct. The lie of the rock in the quarry, regarded in conjunction with the build of the main mass at Peldar Tor, suggests intrusion. As has been strongly emphasized in the paper, however, there is now no undisputable evidence of contact alteration on its margin (phenomena noticed and recorded by Professor Watts). At the same time to regard it as a lava involves greater disturbance of the units which make up the hill than field evidence warrants. The main difficulty in accepting the idea that the Peldar Porphyroid is intrusive into the "coarse agglomerates" is the fact that lenticles of the intrusive rock and detached irregular fragments of it are found in the tuffs. To interpret this way entails two Peldar Porphyroids, one prior to the formation of the clastic rock and one subsequent to it—this is unlikely. The recognition of the Purple Porphyroid as a separate unit and of the Good Rock as a later intrusive offers a satisfactory solution to what is a bewildering problem to the casual observer in these quarries. Reasoning from the enclaves, which are found in the porphyroids as well as the breccia, the data on which the relative age of the various rock units of Bardon Hill are obtained, are :—

The rock from north to south is

A. Peldar Porphyroid.
B. Purple Porphyroid.
C. Bardon Breccia.

The enclaves in A, B and C respectively may be expressed by index letters thus :—

A contains xenoliths of x and y.

B contains xenoliths of A and of x and y.

C contains a few xenoliths of A, and many of B, these abundant near the flank of C nearest to the masses A and B ; also xenoliths of x and y and others not found in A and B.

The simplest interpretation of these facts is that C is later than B, and B later than A. That is, the part of the Bardon Rock considered to be intrusion breccia, is newer than the Peldar Porphyroid. The abundance and variety of the enclaves of both Porphyroids and breccia calls for explanation. The invasion of a pre-existing tuff by first the Peldar, then the Purple Porphyroid, and finally by what is now, without its enclaves, termed Good Rock, explains clearly to the author the observations recorded in this paper. The freshness of the porphyroids as compared with the Good Rock, is not an insuperable objection to the argument, since chemical composition may play the chief part here ; also the Breccia is admittedly a mixture—a mixture of clastic material of variable coarseness with a welding igneous material. The author has been strengthened in his views quite recently by discovering similar phenomena on a much smaller scale in the igneous rock of Groby where a dyke rock intrusive into the "Syenite" has brecciated it and welded the fragments into a rock not dissimilar to many parts of the Bardon Breccia.

In regard to the pre-existing tuff, certain enclaves in the breccia are strongly suggestive of Slate Agglomerate in appearance, and are consistent with that rock in Sp. G. There is not enough evidence to identify them absolutely, but the possibility that the intrusives just referred to, broke through tuffs of which the Slate Agglomerate is a residual portion, should be noted—the cleaved character of this rock as contrasted with the uncleaved Bardon Breccia is perhaps significant.

In venturing on investigations akin to the above, the beginner is always greatly in debt to his fore-runners for guidance. Much of this is impersonal, but nevertheless very deserving of acknowledgment; in addition I have to thank Dr. Bennett for his great help in the field and Dr. Lowe, of the Leicester Museum, for access to specimens and slides.

A Preliminary Survey of the Geology of Sark.

By GEORGE HORACE PLYMEN, M.Sc., Ph.D., F.G.S.

THE island of Sark lies 7 miles to the east of Guernsey. Its length from north to south is over 3 miles, and its average breadth is one and a half miles. The island is a table-land with an average height, above sea-level, of 300 feet, probably a result of marine planation of Pliocene date. Access is accomplished by scaling the cliffs of Havre Gosselin (west coast) or through the tunnel of Creux Harbour (east coast). The southern portion, Little Sark, joins the mainland by an isthmus 8 feet wide, 250 feet high, and 300 yards long, known as La Coupée. Here, as in many parts of the island, the cliffs drop sheer to the sea, and considerable care is required in examining the rocks.

The island is characterized, in common with the other of the Channel Islands, by a notable absence of fossiliferous beds. The rocks are exclusively igneous and metamorphic, and display resemblance to pre-Cambrian suites in other parts of the globe. They may be paralleled in the North-West Highlands and at the Lizard. In a remarkably close degree they resemble the pre-Cambrian of the Southern Eyre Peninsula, recently admirably described by Dr. C. E. Tilley.[1] The base is dioritic gneiss, occupying more of the island than the coastal platform suggests. A complex of aplite and hornblendite overlies this, and a series of hornblende-schists and amphibolites is superposed. The hornblende-schists, where best developed, grade upwards into micaceous, sandy schists. Their lowest beds alternate with the hornblende-schists.

The dioritic gneiss is an ortho-gneiss and as it invades all of the superposed beds, it is apparently the youngest rock of the series. It gives rise to a noteworthy lit-par-lit structure in the hornblende-schist and the mica-schist.

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[1] *Quart. Journ. Geol. Soc.*, vol. lxxvii, No. 306, part ii, 1921, pp. 75–134.

PREVIOUS INVESTIGATION.

MacCulloch, Prof. Ansted, Prof. Liveing, J. A. Birds, Prof. Bigot, Rev. Canon Hill, Prof. Bonney and Dr. J. Parkinson have contributed to the geological literature. The main work was accomplished by Canon Hill and Prof. Bonney, afterwards summarized by Dr. John Parkinson.[1] The present work was undertaken to provide more detailed mapping, and to study the tectonics, of the island.

THE SEQUENCE OF THE ROCKS OF SARK.

The succession of the beds is best studied at the Hog's Back, a promontory in the south of the island, between Dixcart Bay and Creux Derrible. The Hog's Back is easily reached, the cliffs are accessible from sea-level, the beds are practically horizontal, and every type of the Sark rocks is seen there. The downward succession, from highest to lowest beds, is as follows :—

HOG'S BACK SUCCESSION.

		Feet.
D. (ii)	Mica-schist	22
D. (i)	Mica-schist (alternating with hornblende-schist)	52
C. (ii)	Hornblende-schist (with intrusive bands of diorite-gneiss and rare mica-schist bands)	73
C. (i)	Hornblende-schist (with diorite-gneiss in lit-par-lit.)	31
B. (iv)	Hornblendite-Aplite series (narrow banded)	36
B. (iii)	Hornblendite-Aplite series (with broad banded gneiss intrusions)	27
B. (ii)	Hornblendite-Aplite series (narrow banded)	12
B. (i)	Hornblendite-Aplite series (with numerous intrusions of diorite-gneiss)	52
A.	Diorite-gneiss	*unknown*

GENERAL SURVEY.

From the south coast, eastward, there is a notable uniformity in the lie of the beds. The whole of Dixcart Bay, Creux Derrible, and Petit Derrible, to Creux Brown, shows the gneiss platform surmounted by the hornblendite-aplite series, with the higher cliff tops exhibiting hornblende-schist banded with mica-schist.

From Creux Brown to Les Cagnons, past Creux Harbour, faulting brings up the diorite-gneiss into higher cliff sections, and only the hornblendite-aplite series lies above. Throughout this portion of the coast the strike of the beds coincides with the coast-line. The westward dip is very slight, and only valley sculpture brings in beds lower than the hornblende-schist in inland exposures. An exception is seen at Collinette, Peignerie, and La Forge, this area exhibiting diorite-gneiss irregularly intruded into the overlying rocks so maintaining a relatively high horizon. At Les Laches, south of Creux Harbour, one is particularly struck by the close resemblance of the hornblendite-aplite series to the Kennack gneiss. In this quadrant of the coast, also, the lit-par-lit structure is very much in evidence. It applies equally to the mica-schists as to the lower beds. In conjunction with this effect the broader banding of diorite-gneiss, along the strike, is marked at all horizons. Some

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[1] *Handbuch der Regionalen Geologie*, Band iii, I Abteilung, p. 334.

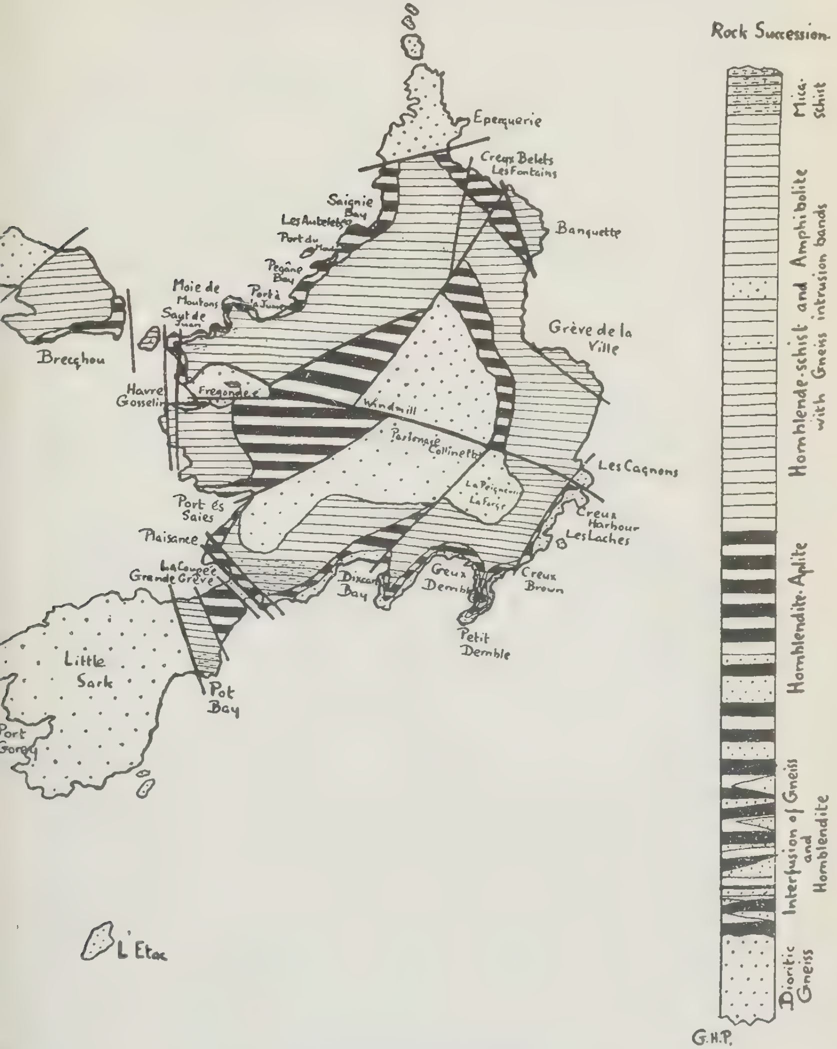

FIG. 1.—Geological map of Sark.

of the bands, especially at lower levels, are pegmatitic or granitic and there is much epidote banding particularly in the hornblendite series. The gneiss, although it is injected into the whole of the rocks of Sark, is itself caught up in xenolithic form in the pegmatite veins, which carry in their flow both diorite-gneiss and hornblendite. The junction of gneiss and hornblendite-aplite series at Les Laches suggests a gradual absorption of the latter by the former.

On the east side of Dixcart Bay, the lower exposures of the hornblende-schist series show a platy, ashy appearance, remarkably like the andesitic ashes at Vicard Bay in Jersey. The weathering of the rock would appear to have produced reversion to a condition somewhat resembling the original state.

From Les Cagnons, past the lighthouse, along Grève de la Ville, and from Banquette Point to Creux Belet, the dip changes definitely to east and to north-east and increases to about 30°. Except for two interesting normal faults, there is no break in the continuity of the hornblende-schists. The lower beds are met occasionally inland, but only in rude outcrops in the primitive lanes and paths of the island.

As at Dixcart, at Grève de la Ville the hornblende-schist, notably to north of the stream by which access to the shore is gained, exhibits the characteristics of a basic-ash. Above this apparently decomposed portion, the rock is characteristically crystalline and schistose, and quarries are worked for house building, the fissility and durability of the schist recommending it as a local building stone.

From Creux Belet and Les Fontains to Eperquerie, to the south of which is the fault which brings up the northern gneiss, the strike curves gently, giving a dip veering E.S.E. to N.E. to N.N.E. The gneiss platform is seen again, surmounted by the hornblendite and the hornblende-schist series. In this portion the mica-schists are completely eroded, the altitude of the island being considerably less than we find further south.

The northern gneiss area occupies the northern promontory of the island, the reverse fault which brings it up also appearing in Saignie Bay on the west coast.

From Saignie Bay southward to Port du Moulin and on to Pegâne Bay, the effect noted in Les Fontains is seen again, the beds arching or doming. In Saignie Bay they dip gently and slightly to N.N.W., at Port du Moulin they are horizontal, and in Pegâne Bay they dip to S.W., with a low angle. The gneiss is well exposed in the three bays, notably in Port du Moulin. The principal phenomena of metamorphism are best studied in this part of the island, the hornblendite-aplite series and the hornblende-schists being particularly well delineated. It is seen here that the gneiss is inconsequent in level, occupying varying altitudes in various parts; the evidence is, however, seriously complicated by faulting. Minor faults of a very picturesque appearance uplift the beds from Port du Moulin, Les Autelets and La Saignie in three stages in diminishing amount, suggesting relative downthrow by excess upthrow at Port du Moulin. Inland in this part of the island, the hornblende-schist alone is in evidence, until dislocation occurs in the Creux Belet Valley fault.

From Pegâne Bay, through Port à la Jument, to Moie de Moutons and Havre Gosselin, the beds are mainly hornblende-schist, surmounting the hornblendite-aplite series. Gneiss is only seen in local intrusive tongues, or in the neighbourhood of small faults. Quarries of schist are found near Saut de Juan. The crystalline hornblende-schist is the rock for which the quarries were opened, but the overlying mica-schists are well developed. They are remarkably well banded with pegmatite, and this is the best area for their study and for lit-par-lit phenomena. There is not much opportunity for viewing successions, for the dip agrees with the slope of the island, and one scarcely does more than traverse the bedding plane in making a descent. There is interesting corrugation in the schist here, evidence of subsequent transverse pressure. At Frégondée and on the northern slope of the Gosselin Valley, to the north of the Pilcher Monument, the gneiss is seen in intrusive relation to mica-schist, the latter overlying it in two areas.

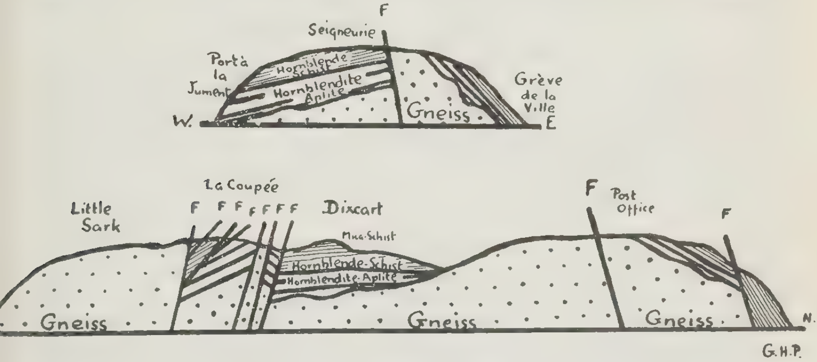

FIG. 2.—Sections illustrating the geology of Sark.

From Havre Gosselin to Port és Saies the beds dip at 20° to 30° to a little S. of W., bringing in a good exposure of the hornblendite-aplite series on the north side of Port és Saies, where faulting on the south side destroys the symmetry. This bay, however, while accessible—one uses the cable supplied by the fishermen—is not helpful to the study of metamorphism. Shatter-belts are so well developed and so numerous as to give masses of ochreous clay almost as wide as the bay itself. At least two faults of importance are evident here.

From this point southward to La Coupée, past Plaisance, and, on the east coast, from Dixcart southward to La Coupée, the beds are accessible only by boat. They are mainly of hornblende-schist, with mica-schist capping in places, but are not specially suitable for close examination.

The diorite-gneiss intrudes high into the upper series, sometimes reaching the surface of the island. The dip is to some extent to N.W., but is complicated by the persistent reverse faulting of which La Coupée is an expression.

From La Coupée southward to the "Chapel", Grande Grève, and (on the west coast), to a point north of the "Pot", the repeated upthrust of reverse faulting gives an apparent southward dip, in which gneiss and schist occur out of their due relationship. The effect culminates in the faulting up of a mass of diorite-gneiss, of which most of Little Sark consists.

TECTONICS.

The main phenomena are the igneous intrusion of the dioritic gneiss into the upper beds, and the fault-thrusting. Although the gneiss in its present position is the latest in time, it is the basement bed of Sark wherever it is found. To the north-east of Havre Gosselin, and to the east of Port és Saies, it has intruded itself through the whole of the Sark series. In other parts, notably at Port du Moulin and Pegâne Bay, it has intruded high into the hornblendite-aplite series; and in all parts of the island it occupies isolated bands at various horizons, as shown in the Hog's Back succession. The general form of the island is due to the platform of gneiss on which the upper beds rest, and the wave erosion has in most parts reached the resistant gneiss, protecting the beds above. The most picturesque scenery is noted to west of Havre Gosselin, where the isolated islands of hornblende-schist show various stages in the process of total destruction. They indicate that time alone establishes a difference between them and the islands of the extreme south and north, where denudation has completely bared over a hundred of them down to the tenacious gneiss.

The main faulting in Sark is expressed in directions roughly parallel to the length of the island. The eastern portion is thrust in reverse faulting against the western. The movement was greater in the northern half of the island, and a transverse fault resulted from Creux Harbour to Havre Gosselin. A broad shatter belt has been produced in Havre Gosselin, with, however, very little change in facies on either side, the faulting being lateral. The effect of this transverse fault is to dislocate the main fault into two planes. The southern fault plane is seen from Port és Saies to the Parsonage running in a N.E.–S.W. direction, indicated clearly by a system of fault-guided valleys; the eastern side of these valleys exhibits gneiss at several points, brought up against the hornblendite-aplite series. The northern half of the fault-plane has its trace indicated from the Windmill to Creux Belet. The Creux Belet valley affords a good instance of a fault-valley but normal faulting to south of Creux Belet obscures the evidence on the north-east coast. The fault-trace from the Windmill to Creux Belet runs N.N.E.–S.S.W., having a slightly more northern trend than the southern portion.

The beds are almost horizontal on the north-west coast, but dip roughly to the north-east on the north-east coast. On the south-west coast the dips are to the south-west, while on the south-east coast the beds are again horizontal, slightly inclining to the west. From Creux Brown to Les Cagnons, however, this horizontal trend is obscured by the reverse faulting, parallel with the main faulting, of the gneiss of Creux Harbour. There are three well-marked normal faults on the east. The principal of these is the Dixcart fault, occupying Dixcart Valley. It shows a fine shatter-belt in Dixcart Bay, fault detritus and ochreous material occupying over a hundred yards of the bay. The downthrow eastward, however, is slight. Another normal fault runs from Grève de la Ville in a south-easterly direction. A large dolerite dyke occupies the fault-plane, and the normal faulting to N.E. was subsequent to its intrusion. The third normal fault runs from the east of Creux Belet to S.S.E. The relation of the two latter faults to the general fault system is not clear, and their age is not evident.

On the west coast, balancing the upthrust of the Creux Harbour gneiss on the east, is the reverse faulting of the gneiss of the west of Breqhou and the normal faulting of the Moie de Gouliot. When we turn to the northern and southern extremities of the island, this symmetry of upthrust becomes specially interesting, and one is tempted to compare the structure with the plagioclinal ridge of Calloway.

The northern gneiss is upthrust along an E.N.E.–W.S.W. fault-plane, seen south of the Eperquerie and, on the west coast, in the more inaccessible cove north of Saignie Bay. There are repeated fault lines to the north seen in the gneiss area, and a very large number of dolerite dykes running in the same direction as the fault. The caves which give expression to this movement are very numerous, and usually dripping with fresh water and giving harbourage to many beautiful ferns, notably *Asplenium marinum.* On both the east and west coasts, south of this upthrust, the hornblende-schists and the hornblendite-aplite series arch along an axis parallel to the fault plane as if the softer beds bent and the harder rock shattered, under the great pressure.

The south of the island gives a more interesting instance of the upthrust of diorite-gneiss, for the whole of Little Sark illustrates it. The phenomenal ridge of La Coupée is no more than fault-breccia, rubble, and ochreous material exhibiting reverse faulting from the south. From the north side of La Coupée to its centre are three repetitions of upthrust, and, south of La Coupée, at least six parallel fault-planes illustrate the upthrust of Little Sark. The beds of schist and similar material have accommodated themselves to the faulting by a high dip to S.S.W. The parallel fault-planes run N.W.–S.E. almost at right angles to the similar planes of the north of Sark. Both in Grande Grève on the west coast, and north of Pot Bay on the east coast, the faulting can be examined at low tides. Access to the shore down the west side of La Coupée is not impossible, and the descent of the "Pot" though difficult is commonly made. As in the north of the island, the fault-planes are occupied by caves, tunnels, crevices, and dolerite dykes, which contribute largely to the fascination of the scenery.

To summarize the main facts, great pressure, exerted mainly from the north-west or the south-east, has fractured the island, bringing up the lowest and hardest rocks in the west, north, south, and east, and produced a fracture, now dislocated, from Port és Saies to Creux Belet, running N.N.E.–S.S.W. The Dixcart Valley fault belongs to the same movement.

The period of faulting is not evident, but the rocks of Sark, older and more subject to deep-seated readjustments than those of Jersey, have experienced all earth movements, from pre-Cambrian to the present day. In Jersey the main pre-Cambrian fracture lines run north to south and east to west. The Sark fractures are presumably pre-Cambrian, the Armorican movement having probably expressed itself along similar lines.

It is a fact worthy of note that the Port és Saies-Creux Belet line is in the line of Alderney, of the channels known as the Great Russel, the Little Russel, La Deroute, and the Race; and the Creux Harbour-Havre Gosselin fault coincides with the Cobo Bay–St. Peter's Port fracture line in Guernsey, and the north coast of Jersey, itself a fault line.

MINOR INTRUSIONS.

Sark is ramified by dykes of a doleritic nature in innumerable quantity. It is scarcely an exaggeration to state that they occur at intervals of about every 20 yards and they could be mapped only by a permanent resident. The small scale maps now in use are quite inadequate for the purpose. There is no standard direction to be noted, but a very large number run east to west, notably at Eperquerie, and many run north to south in Little Sark. They are far less common in Alderney and in Jersey. As in all of the islands, they are the origin of numberless caves, channels, and arches. There are both pre-Cambrian and Permo-Carboniferous dykes.

A lamprophyre dyke, 4 feet wide, comparable with the Jersey dykes of "mica-trap", traverses the south side of La Coupée. It is not easily seen in the accompanying fault rubble.

ECONOMIC.

Only the absence of good harbours has prevented the development of quarrying in Sark. There are no rocks in Jersey, Guernsey, or Alderney superior to the diorite-gneiss. It is utilized in the island as a building stone, and its use could be extended for ornamental buildings, harbour works, curbstones, setts, and road metal. As a local building stone, also, the hornblende-schist is much utilized, its quarrying being comparatively easy. If such harbours as St. Sampson's (Guernsey), Braye Harbour (Alderney), and Ronez Harbour (Jersey), were established, valuable building stone could be extracted in any part of the island.

In 1825 workings for silver were opened in Little Sark, at Port Gorey. The silver was found in argentiferous galena in discontinuous pockets in crevices in the diorite-gneiss; but by 1832 it was found that insufficient silver existed to pay expenses and the local promoters were ruined financially.

No known lead veins are now found, but some of the discarded nodules may be examined on the old tip-heaps. Galena is enclosed in haematitic iron oxide, altered to pyrites. The exterior surfaces of the nodules are limonitic. The amount of galena is not great, in some nodules it is absent, and the writer has found no traces of silver in many samples but a slight trace in one. It would appear that the pneumatolytic or hydatogenetic action supplying the ore, deposited it in veins now denuded away, and only casual deposits occur in the portion remaining.

The numberless caves and rock fissures supply abundant quartz in pyramidal form. Much of it is amethyst-quartz supplying the local gem-stone known as Sark Stone. Other colours occur, but most of the "Sark stones" sold in the island are imported.

The water supply, as in all the Channel Islands, is surface water. The wells are not deep, and less than a 30 ft. boring will produce a "permanent" supply. The 1921 drought, however, severely affected the inhabitants. Except at the four hotels, the Seigneurie, etc., water is used solely for domestic purposes and not for sanitation. Dams and reservoirs in the Dixcart Valley or the Grève de la Ville stream, could supply all possible need the island might have to meet in the future, and good springs could be tapped at localities like La Forge.

The writer has to express his appreciation of Mr. S. W. Wooldridge's valuable advice on the petrology of the island, of the help of Mr. H. W. Cornes, and Mr. and Mrs. A. J. Robinson. The Royal Society Government Research Committee enabled accomplishment of the work by making a substantial grant.

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Different Explanations of the Bilateral Symmetry in the Rugose Corals.

By Professor N. N. YAKOWLEV, Leningrad.

IN the bilateral symmetry of the Rugose corals it is the general form of the polyparium, presenting a cone bent in the form of an oxen horn, that strikes at once the observer's eye and obliges him to seek for an explanation.

This peculiar form of the corallum has been already pointed out by Neumayr (*Die Stämme des Thierreiches*) as characteristic for the whole group of the *Rugosa.*

It was the German palaeontologist Weissermel who first approached the question of the morphogenesis of the *Rugosa polyparium.* In his paper of 1897 " Die Gattung Columnaria und Beiträge zur Stammesgeschichte der Cyathophylliden und der Zaphrentiden ", Weissermel opposes the radially symmetric colonial *Rugosa* to the bilateral symmetric representatives of the same group. Weissermel expresses the opinion, that every individual of a colony had a tendency to maintain the crown of its tentacles expanded in the direction of the nutritional area of the surrounding corallites, a tendency to develop regularly in all parts. It stands otherwise with the noncolonial, solitary corals, which were able to turn their tentacles and the whole peristomial surface in one direction, namely towards the prevailing supply of food materials, as, for instance, in the case of a constant sea current of surf. Hence resulted the hornshaped form of the polyparium so frequent among the solitary corals. At the same time, as the superior half of the calice, exposed to the current, received a greater amount of food materials in comparison with the inferior one, its growth was accelerated and disorder was brought in the radial arrangement of the septa. If one-half of a circular calice develops more intensely than the other, in other words becomes elliptical, then its septa, which were equal in number in both halves, must diverge, forming broader interseptal cameras, or the number of these septa must increase. The latter takes place in our case, as result of a more abundant nutrition and, at the same time, in order to utilize still better the supplied food by means of an increase in the number of tentacles.

In consequence of the introduction of new septa their arrangement in the whole upper part of the calice becomes pinnate. The bilateral symmetry of the one half of the calice may be transmitted to the other.

Weissermel notes, that he has been guided to the idea of his hypothesis by an analogous consideration of Jaekel concerning some sea-lilies, whose inequilateral development was stimulated by the action of a food-supplying surf.

As regards Weissermel's hypothesis, the following may be said: firstly, it is evident that a comparison of solitary corals with sea lilies has no foundation, since sea-lilies feed on microscopic organisms constituting the plankton, which is passively driven on by a flow of water, while the coelenterata possess tentacles by means of which they are actively seizing their prey, the latter being sometimes equal in size to the animal by which it is devoured. That sort of prey cannot be passively transported by water currents; moreover, animals provided with long and flexible tentacles, do not depend, while hunting, on the direction from whence the prey is approaching them. Thus, the inclination of the mouth towards the prevailing current cannot have the significance which Weissermel wishes to attach to it.

Further on, the author's declaration, that the upper half of the calice was more intensely developed than the lower one, as the result of a more abundant nutrition, presents a simplified physiological conception of the process of nutrition, which cannot be accepted.

In considering Weissermel's explanation one is obliged to guess, but all the same it is difficult to comprehend, why the arrangement of the septa becomes pinnate and why it is pinnate on the one side of the lateral septa and parallel on the other. The last question is not at all considered by Weissermel and one cannot imagine how this arrangement could be explained by means of his hypothesis.

Lastly, it is incomprehensible, why the bilateral symmetry of the superior half of the calice must be, as stated by Weissermel, transmitted to the inferior one.

Another attempt to explain the organization of the Rugose corals was made by the English Zoologist, H. M. Bernard. The hypothesis set forth by Bernard, in 1904 (*Ann. & Mag. Nat. Hist.*, ser. VII, vol. xiii) is as follows: A conical Rugose polyparium is primarily attached by its apex, but that sort of attachment being not solid, the corallum soon breaks off from the substratum and lies down on one of its sides, by which it becomes secondarily attached. Later on, the corallum tends to re-establish its vertical position, growing on in such a manner that it seems to be turning away from the bottom. One cannot admit that Bernard is giving an explanation of the characteristic arrangement of the septa in

Rugose corals, since the following words could hardly be taken for such a one: "It is obvious that, as the coral is bending to the vertical, seen from above, the septa would have the arrangement shown in diagram Fig. 6, which is after the classical figure of Kunth." "Further, it has long been known that, as such corals gradually reacquire a vertical position, the septal arrangement slowly gives up the bilateral and returns to the radial. Thus the character on which it was proposed to found a great division of the stony corals was nothing but a slight mechanical adaptation to a passing phase in the life of each individual coral" (pp. 11, 12).

Thus the Tetracoralla could, according to Bernard, have originated in different epochs, but, in contradiction to Bernard's hypothesis, such facts have not been observed in reality.

Thus we see that both Bernard and Weissermel, in order to explain the internal bilateral symmetry of the Tetracoralla, are basing on the coral's external bilateral symmetry, that is on the bent state of the polyparium, but in the same time their explanations of the latter are different. Weissermel supposes it to be the tendency to bend towards the current, while Bernard starts from the position of the polyparium lying sidewise upon the ground, although it is not obvious that such a position has been observed by him. All his figures are schemes, often absolutely theoretical ones.

My own explanation [1] of the organization of the Rugose corals was deduced from a fact first pointed out by myself, namely, that of the lateral attachment of the Rugose corals, so that in this respect my explanation is rather agreeing with Bernard's hypothesis. But I am basing on a fact firmly established by me—the fact of lateral fixation, which is moreover primary, not secondary, as in the hypothesis of Bernard, who supposes that the lateral fixation is following the primary axial one, the latter being effected in such a manner, as if the apex of the corallum had been truncated. According to my observations, the axial fixation is an exclusive character of the Hexacoralla.

Further, my explanation of the internal arrangement of the septa results from considering the influence of two factors: that of the bent condition of the polyparium and that of the inclination of its mouth's plane in the one or the other direction (towards the convex or the concave side of the corallum), which inclination has been concretely observed by me.

I explain the curvature of the polyparium by a tendency of the mouth to avoid the neighbourhood of the ground, which is the more natural in the case of a lateral attachment; I explain the latter—by the life in shallow seas, since that sort of attachment is leading to a solidity of fixation indispensable in these conditions.

The polyparia disposed on the sea bottom are orientated in a definite way, but, in opposition of Weissermel's supposition and according to my own views, they are turned, in order to resist the influence of currents or water with their convex side towards the current—a position most advantageous from a mechanical point of view.

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[1] Organization of Rugose corals and Origin of characteristic Peculiarities, GEOLOGICAL MAGAZINE, 1917, p. 108.

In a review published in 1914 and dealing with one of my works [1] (Die Entstehung der charakteristischen Eigentümlichkeiten der Korallen Rugosa) Weissermel expresses himself concerning the explanation given by me as follows : " Die Auffassung der bilateralen Symmetrie als Folgerscheinung hornförmigen Wachstums entspricht durchaus derjenigen, die Bef. früher in einer Arbeit geäussert hat, die dem Verf. anscheinend unbekannt geblieben ist. *Zeitschr. d. Deutsch. geol. Ges.* 1897, p. 865 : Die Gattung Columnaria und Beiträge zur Stammesgeschichte der Cyathophylliden und Zaphrentiden."

My explanation " entspricht " as much to the explanation of Weissermel as to that of Bernard, the three having but that in common, that all of them are based on the shape of the polyparium bent in the form of an oxen horn, but further they are proceeding independently from one another and on different ways.

It may be, that I had been formerly acquainted with Weissermel's paper, but I have evidently not given attention to the last two pages consecrated to the question of the general origin of the Rugosa, a negligence the more likely expected, as the title of this work gives no reason to suppose that the author is engaged in the study of so general a question. It seems that in this respect nobody gave attention to this paper until 1921, when Broili,[2] probably on account of the above cited statement of Weissermel (the review of 1914), expressed himself as to the identity of both Weissermel's and my views and mentioned them as parts of one and the same theory, taking from Weissermel's hypothesis the explanation of the pinnate arrangement " durch Zerrung des Kelches " and from mine—the lateral fixation (which *Weissermel* has not in the least had in view, since, on the contrary, he very distinctly represents in his restoration of a *Rugose corallum* an *axial* fixation of the latter).[3]

It still remains to mention the hypothesis of Gerth.[4] Adopting my views on the existence and significance of a lateral attachment (s. 208) he holds the influence of the latter to be in some respects more far reaching, namely, he supposes that the lateral fixation may likewise affect the form of the internal cavity of the polyparium, which became, according to his supposition, flattened on the convex side (Dorsalseite).

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[1] *Neüs Jayrbuch*, 1914, II Bd., 2 Heft, S. 333–4.

[2] Zittel, *Grundzüge der Palæontologie*, s. 96. *I Abteilung. Invertebrata*, 1921. See also *Grundzüge der Palæontologie*, 1924, s. 100.

[3] This figure, certainly not corresponding with real facts, has been reprinted by Dacqué, *Vergleichende biologische Formenkunde*, s. 425.

[4] H. Gerth, " Ueber die Entstehung des Septalapparates bei den palaeozischen Rugosen und bei lebenden Korallen " : *Zeitschr. f. induktive Abstammungs u. Vererb. Lehre*, 1919, Bd. xxi, Heft 4.

"In der durch seine innere Organisation rechten und linken Seite bekam das Tier nun auch eine durch äussere Verhältnisse Vorder und Hinterseite, eine abgeplattete Dorsal- und eine gerundete Ventralseite. Hierdurch waren die Vorbedingungen geschaffen für eine bilateral symmetrische Anordnung der Septen und Einschaltung in nur vier Interseptalräumen, gegenüber der radialsymmetrischen auf der kreisrunden Fussplatte der jüngeren Korallen."

It remains incomprehensible why the development of the septa is reduced only to four quadrants from the six primary ones, since both four and six may present a radial symmetry as well as a bilateral one. And first of all it is uncertain on what his assertion as to the flattened form of the internal cavity of the polyparium in the early stages of its development is based. These corals have been repeatedly studied by many authors whose figures state that the transverse section is always circular, but never semicircular or something like that, as it is supposed by Gerth.[1]

A flattened condition of the corallum, due to the lateral attachment, exists but on the external surface of the body wall, which often spread in growing, in order to adhere to the plane surface of the substratum.

Gerth is supposing that the primary semicircular section, which is, in later stages of development, when the coral begins to turn away from the substratum, subsequently replaced by a circular one, may sometimes be preserved in adult age, as, for instance, in *Calceola* and *Holophragma*, thus presenting genera of a primitive type. This statement is, no doubt, erroneous, since a flattened state of the convex side of these corals is a secondary adaptation due to the loss of the lateral attachment to the substratum. Moreover, particularly *Calceola* must be considered as a most specialized genus.

The theories of Weissermel, Bernard and Gerth are inconsistent; they stand in contradiction with real facts and even, if they are adopted, they do not wholly explain the bilateral symmetry of the Rugose corals.

On River Sand from the Ure and the Ouse above York.

By Sidney Melmore, B.Sc., F.G.S.

THE sand described in the following notes was dredged from the mid-channel of the river at the following places:—Swale Nab, Dunsforth, Aldwark Bridge, below Linton Lock, and Beningbrough. Two samples were also obtained from the Nidd at points 100 and 200 yards respectively from its confluence with the Ouse.

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[1] Gerth himself does not adduce photographs of such sections, while his schematic sketches (*Palæontologie von Timor IX Lief. Die Anthozoen der Dyas von Timor*, s. 141, fig. 12) cannot prove the existence of the latter. If Gerth really possessed such sections, they possibly had been obtained from corals previously deformed in the rock.

For comparative purposes sand from the banks and alluvial flat of the Swale above Ainderby Steeple is likewise included.

THE FORM AND AVERAGE SIZE OF THE GRAINS.

The grains are subangular to angular in form except the opaque particles of limonite, which are sometimes markedly rounded in outline. The average diameter of the grains is 0·37 mm. (excluding the sand from the Nidd and the Swale alluvium), ranging from 0·53 mm. on the average at Aldwark Bridge to 0·27 mm. at Linton Lock. There is no regular decrease in size on passing downstream owing to the meandering of the river.

The Nidd for the last half mile of its course runs due north, and for this reason there is a strong tendency for its mouth to be silted up with the material brought south by the Ouse. The top of the bar formed in this way can occasionally be seen above the surface of the water at Nun Monkton. The sand deposited here is coarser (0·43 mm. in diameter) than at Linton Lock (0·27 mm.) and Beningbrough (0·32 mm.).

THE COMPOSITION OF THE SAND.

Apart from quartz and felspar, quartzite grains and angular fragments of chert sometimes containing traces of organisms are fairly common. A composite grain of quartz and plagioclase has also been noticed. The minerals with a density greater than that of calcite (2·72) were separated in Sonstadt's solution. These make up from 3 to 5 per cent of the sand by weight. Of this heavy portion about 0·8 per cent can be extracted with a horse-shoe magnet. The magnetic matter consists of magnetite and other grains of a dark purple colour. In the samples from the Nidd the proportion of heavy minerals rises to nearly 6 per cent, but of this only about 0·4 per cent is magnetic.

While grains of zircon, rutile, apatite, brown tourmaline, garnet, muscovite, and hornblende occur, by far the greater part of the heavy fraction is made up of limonite, fluor-spar, barytes, and a little dolomite, in that order of frequency. The presence of fluor-spar and barytes distinguishes this sand from any other in the neighbourhood of York.

Only the last four minerals require special description.

Limonite occurs in grains with an average diameter of 0·4 mm., frequently well rounded.

Fluor-spar.—Only one grain having a faint purple tint has been noticed; the rest are colourless. Triangular cleavage-forms are fairly common, but most of the grains are irregular in shape (average diameter 0·28 mm.), though always markedly angular. Some contain intersecting rows of tubular inclusions.

Barytes.—This mineral appears in the form of plates with an average diameter of 0·18 mm. bounded by the traces of *m* (110), sometimes modified by an irregular concave outline. Such plates present a speckled appearance (Fig. 1, *F*), arising out of the scaly character of the cleavage-face *C* (001). Cases are frequent in which these cleavage plates have experienced secondary growth. This process has resulted at times in the formation of a variety of crystal forms. Thus the grain found in a sample of the alluvium of the Swale above Ainderby Steeple (Fig. 1, *A*) exhibits *C* (001), *m* (110), *d* (102), *o* (011). The grain from Dunsforth figured at *B* is somewhat similar, but being larger it is more rounded. In some cases the interference colours show that this secondary matter is not always of uniform composition, but alternate layers of an isomorphous substance.

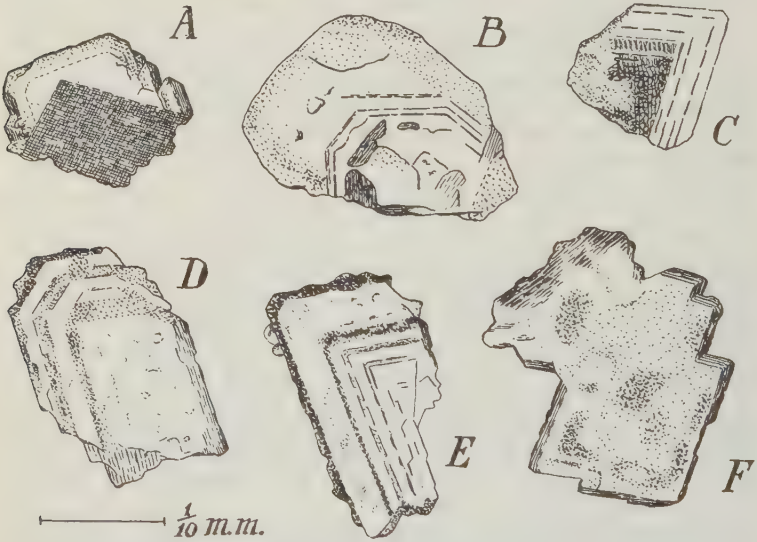

Fig. 1.—Barytes from River Sand. *A*. showing development of faces by uniform secondary growth upon a cleavage form. *B*. Crystal forms developed as in *A*, but faces rounded and less distinct owing to weaker internal reflection. *C*. Intermittent growth, but uniform composition. *D* and *E*. Intermittent growth. In the latter case the layers are of varying composition. *F*. More common type of cleavage form without secondary growth. *A*, *D*, *E*, from the alluvium of the Swale. *B*, *C*, *F*, from mid-channel at Dunsforth. All drawn as seen in ordinary light.

Dolomite occurs in subangular fragments having an average diameter of 0·32 mm., though sharp-edged rhombohedra are also found.

Barytes preponderates to an unusually large extent in the heavy fraction extracted from the alluvium of the Swale, and it has been found a general rule that the finer the sand the greater is the amount of barytes in it, yet the average diameter of the barytes particles in this alluvium is 0·16 mm., or little less than the value 0·20 mm.

for grains of the same mineral in such coarse sand as that from Swale Nab or Linton Lock.

It is interesting to note that although grains of this mineral of a definitely detrital character have been observed in earlier consolidated deposits,[1] none have been described as exhibiting isomorphous zoning.

Columnar Structure in the Nubian Sandstone.

By H. J. L. Beadnell, M.I.M.M., F.G.S.

(PLATE XXIII.)

IN April, 1925, while mapping the coastal plain of the Red Sea south of Berenice for the Egyptian Government, I came across a remarkable example of columnar structure in sandstone, an illustration of which is shown in the accompanying photograph.

Twenty-four kilometres inland, on the right-hand side of the Wadi Kreiga—a tributary of Wadi Hodein, the important watercourse which enters the sea at Bir Shalatein, about 90 kilometres south of Berenice—is a small hillock, the approximate dimensions of which are 100 by 25 by 8 metres in length, width, and height above the surrounding plain. The rock composing the hillock is typical brown-weathering current-bedded Nubian Sandstone, passing in places into the silicified variety and into hard white quartzite. Throughout the exposure the sandstone exhibits an extremely well-developed columnar structure, the individual columns being four, five, and six-sided and from two to five centimetres in diameter. The bundles of columns do not remain parallel throughout the hill. At some points they are disposed horizontally, at others vertically, while in places they are curved and pass gradually from the vertical to the horizontal position. Although common both to the ordinary, comparatively friable sandstone and to the intensely hard quartzite, subsequent weathering has brought out the structure in the softer as compared with the harder variety of the formation.

The presence of remnants of Nubian Sandstone in this area was first noted by Dr. John Ball, now Director of Desert Surveys in Egypt, who mapped the region during the winters 1905–1908. My detailed survey of the coastal plain has shown that the Nubian Sandstone occupies a very much larger area of country than was previously supposed, and also that the formation is here of special interest, being interbedded with thick and widely extended intrusive sheets of basalt and dolerite, in which columnar structure is displayed at several points.

Although no sill is actually visible in contact with the columnar sandstone of Wadi Kreiga, there can, I imagine, be no question but that the structure has been developed during cooling, subsequent to intense heating of the sedimentary rock by a doleritic intrusion.

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[1] H. P. Lewis, " The Occurrence of Detrital Barytes in the Permian Basal Sand at Nitticarhill ": GEOL. MAG., Vol. LX, 1923, p. 307. H. C. Versey, " The Beds Underlying the Magnesian Limestone in Yorkshire ": *Proc. Yorks. Geol. Soc.*, vol. xx, 1925, p. 200.

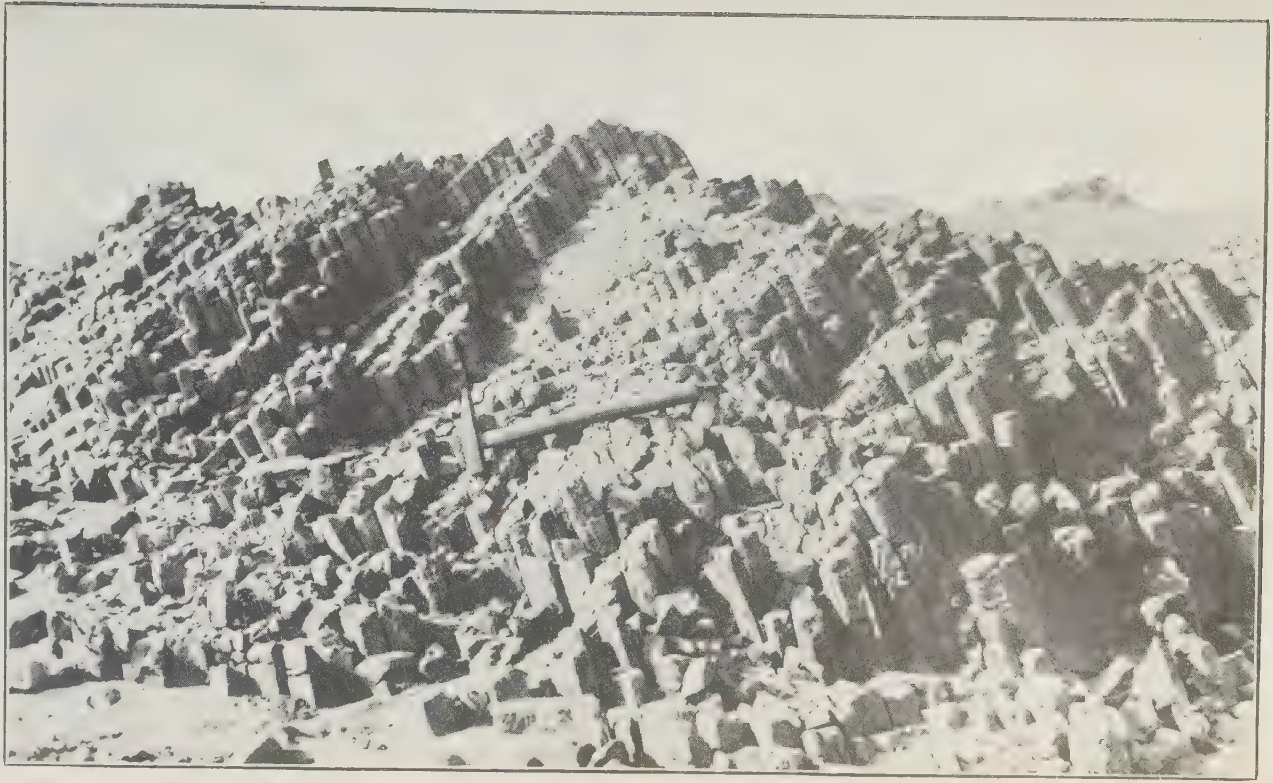
Other examples of columnar structure in Nubian Sandstone are known at Gebel Alarabbia, Gebel Aliberi, and the Kaibar rapids in the Sudan. In Europe the most notable instances of this structure in sedimentary rocks are perhaps those of Dunbar, Scotland; in Switzerland; and at Falcon Clints, Teesdale, Durham.

An Oolitic Rhaxella Chert from Little Hayes, South-East Essex.

By A. Morley Davies, A.R.C.S., D.Sc., F.G.S.

I HAVE been asked by Professor Gregory to examine and describe two pebbles which he has collected from the pre-glacial gravel of Little Hayes, in the Crouch Valley, South-East Essex. Examined in thin section under the microscope, one of these pebbles agrees very well with the typical chert of Arngrove (Bucks) and Studley (Oxon) in size of spicules, their mineralization, their number in a given field, and the proportion of angular sand-grains.

The other is different. At first sight the globate spicules appear larger and are certainly sparser, while interspersed with them are larger bodies of similar shape, stained brown and showing a concentric structure. That both bodies are ellipsoidal is evident from their identical appearance in sections cut at right angles. The larger ellipsoids are silicified oolite-grains, their average dimensions in section being 0·6 by 0·45 mm. The spicules show a thick brown border, identical in appearance with the concentric layers of the oolitic grains. On measuring, the clear, central portion is found to agree very closely in dimensions with the normal Rhaxella spicule (0·15 by 0·1 mm. on the average), but with the brown rim included the average measurements are increased by 50 per cent (0·23 by 0·15 mm.). I take this brown rim as possibly indicating that the spicules were present as such in the calcareous waters in which the oolite grains were growing, and received a slight concentric accretion of calcareous matter. The presence of this calcareous envelope may have had a modifying influence on the subsequent chalcedonization of the spicules, for these do not show the cuspate outlines seen in the typical Rhaxella chert. This cuspate outline (shown as a reticulate pattern on the surface of isolated grains) is almost certainly a secondary structure due to the process of chalcedonization and its absence is no reason for doubting the identity of the spicules. The secondary enlargement of the spicules and the presence of oolite grains partly account for the sparseness of the spicules (little more than a quarter the number in a given area of section, as compared with the ordinary Rhaxella chert), but there is probably a little more of the chalcedonized matrix also.



Columnar Structure in Nubian Sandstone. Wadi Kreiga, Red Sea Coast.

[To face p. 272.

The only variety of Rhaxella chert known in situ which at all resembles this second pebble from Little Hayes is that of Purton (Wilts), to which my attention was called some years ago by Mr. C. E. N. Bromehead. No account of this rock has yet been published, but I have examined its outcrop, which is extensive and is accurately mapped as Lower Calcareous Grit on the Old Series Geological Sheet 34. It differs from the Midland and Yorkshire cherts in having scattered oolite grains, but these are limonitized, not silicified, are larger (one-and-a-half times to twice the diameter, or more) and sparser than those of the Little Hayes pebble. The spicules are identical in appearance with those of Arngrove, showing cuspate outlines and no accretion beyond a thin limonitic film.

The second Little Hayes pebble can therefore hardly have come from either of the three known outcrops of Rhaxella chert (Wilts, Oxon-Bucks, Yorks). In view of the very local and lenticular character of these outcrops (whether due to restricted deposition or to penecontemporaneous erosion) it is quite possible that other outcrops have been completely destroyed by Cainozoic denudation, and the Little Hayes pebbles may be among the products of this destruction.

There is ample space in the interval between Buckinghamshire and Yorkshire for the occurrence of such an outcrop, but I will venture on a suggestion as to its most likely situation. Existing outcrops occur within or on the margin of the area distinguished at a slightly later geological age by the development of the Corallian facies. Whatever special conditions led either to the formation or the preservation of Rhaxella chert may well have been present in an area which bore a similar relation to the Corallian of Upware that the Arngrove area bears to that of Oxford, and it is in Cambridgeshire or Huntingdonshire that I am inclined to locate, quite hypothetically, the lost outcrop from which the Little Hayes pebbles may have come.

The Gravels of Little Hayes, and the Age of the Crouch Valley, South-East Essex.

By J. W. Gregory, D.Sc., F.R.S.

THE rarity of drifts in the Crouch Valley has been often remarked. The only river gravel marked in it on the Geological Survey Map, sheet I N.E., is a small patch at Little Hayes, a couple of hundred yards north of the Crouch, and $1\frac{1}{4}$ miles S.S.W. from Woodham Ferrers railway station. In the *Evolution of the Essex Rivers* (1922, p. 47), an analysis of the five chief constituents, based on a collection made by Mr. H. J. Nicholson, recorded some Jurassic sandstones which I regarded as probably derived from the boulder clay on hills about three miles north and north-west. A visit to the pit last year in order to obtain larger specimens of the Jurassic material yielded various cherts; one is a typical Rhaxella chert, which has not been previously recorded so far to the south-east. A thin bedded oolitic chert, which was different to any that I knew, was submitted to Mr. H. C. Sargent with the inquiry whether it might be one of the Carboniferous cherts of the Midlands. Mr. Sargent identified some of the inclusions as silicified oolitic grains, and rejected the rock as Midland Carboniferous. The specimens and slides were also kindly examined by Professor Boswell, who showed them to Mr. E. T. Dumble for comparison with the Rhaxella chert found by him in the Crag; they also did not know any similar rock. The specimens were then sent to Dr. Morley Davies, who confirmed the identity of the one specimen with the ordinary Oxford-Buckingham Rhaxella chert, and has, in the previous note, described the other as a Rhaxella chert in which the spicules are the nuclei of oolitic grains. Dr. Davies' study of the material shows that the Little Hayes pit contains two varieties of Rhaxella chert, one identical with that of the outcrop in Arngrove, Buckinghamshire; the other, being oolitic, resembles in that respect the Rhaxella chert of Purton discovered by Mr. Bromehead, but it is different from any known outcrop, though as the species of Rhaxella is the same as that of the Buckingham-Oxon-Wiltshire outcrops it is probably from that district. It may have come, as Dr. Davies suggests, from some outcrop to the north or north-east which has been destroyed by denudation. That suggestion seems probable, as the other western material in these early Essex gravels comes from the north of Arngrove, and there is none from so far south as Purton.

The Little Hayes gravel also contains some sandstones which were formed under arid conditions. Professor Boswell remarked their resemblance to the Triassic sandstones. A small fragment of a similar sandstone in the previous collection had reminded me of Northampton Sandstone; but the material is more likely to be Triassic owing to the strongly wind-worn character of its sand grains. The Little Hayes gravel also contains specimens of quartzite from the Bunter conglomerate, but they are extremely rolled and ovoid, and show the effects of long river transport. Two small fragments of chert are weathered like the Lower Greensand Chert. Dr. Morley Davies has kindly examined the slides cut from them, and regards one as a typical Hythe chert; and there is, so far as I know, no other chert which it so closely resembles.

The South-Midland origin of the distinctive material in the Little Hayes gravel recalls the soda-felsite which is found in some of the older Essex gravels. The nearest known source of that rock is the Charnwood Hills; but doubt has been felt as to its origin thence, owing to its absence from the drifts on the direct line between Charnwood and Essex (cf. for example, Salter, 1905; Gregory, *Evolution of the Essex Rivers*, 1922, pp. 32–3). The fact, however, that the older Essex gravels contain Rhaxella chert from the southern Midlands, and fossil wood, identified by Mr. W. N. Edwards as Dadoxylon from Allesley in Warwickshire, indicates that these felsites may have reached Essex by a route from Charnwood through the Southern Midlands and across Buckinghamshire eastward into Essex.

This gravel is of interest in connexion with the age and origin of the Crouch Valley. The best evidence as to the age of this isolated patch of gravel is that of its non-local pebbles. The gravel is marked on the Geological Survey map as post-glacial, which was a natural conclusion from its low level and nearness to the Crouch; and I accepted that view from the probability that some of the pebbles sent me from Little Hayes were derived from the glacial beds. On a visit to the deposit I was surprised to find no material of northern origin, or derived from the boulder clay. All the pebbles that have come from outside Essex had a southern or western origin. That fact renders probable the pre-glacial age of this material, although it may be an old gravel re-sorted in post-glacial times; but as the mammoth remains at Hullbridge, a mile to the east (S. Hazeldine Warren, *Essex Nat.*, xvi, p. 273), occur on the floor of the Crouch Valley, it has not been materially deepened in post-glacial times. That the Crouch Valley was in the main pre-glacial is also rendered probable by the range of the boulder-clay as marked on the Geological Survey map (I, N.E.). The general level of the broad sheet of boulder clay to the north and north-west is at about 200 feet; but according to that map boulder clay occurs at Woodham Ferrers within a few feet of the 100 ft. contour. I know of no exposure there at present; but according to that map the Crouch Valley had been excavated at that village to the 100 feet level before the deposition of the boulder clay; that the central part had been corroded still lower is indicated by the pebbles of the Midland and Lower Greensand Cherts at Little Hayes. The position of the gravel is not inconsistent with a pre-glacial age; the gravel lies on a rise between the valleys of the Crouch and Fen Creek; and both have been deepened and broadened since the gravel was deposited, while the breadth of the alluvium on both sides shows that deposition and not erosion has been for a long time the predominant process.

The evidence shows that the Little Hayes gravel was part of a sheet deposited by a river which rose far to the west and brought with it the Rhaxella cherts and Midland Triassic material. Most of this gravel has been destroyed by denudation, but one patch remains on the low ridge at Little Hayes in the angle between the Crouch and the valley of Fen Creek.

Subterranean Penetration by a Desert Climate.

By E. B. Bailey, M.C., B.A.

THE subject matter of the present note is furnished by the abnormal redness of many parts of the Arran Carboniferous. W. Gunn,[1] in his invaluable memoir, records this colouration without particular comment; but, as Scottish geologists are aware, B. N. Peach,[2] under whose supervision Gunn carried out his survey, has long claimed that the Arran Carboniferous is stained by solutions that have percolated down from overlying New Red Sandstone. After a careful consideration of the exposures, I feel convinced that two features of Peach's proposition are secure :—

(1) The red colour of much of the Arran Carboniferous is not original.
(2) It must be in some way connected with the New Red Sandstone.

On the other hand, I feel justified in modifying Peach's interpretation as follows :—

(3) The red colour has not percolated downwards as a stain.
(4) It has been developed in situ through oxidation of Carboniferous iron by New Red Sandstone air and water.

Briefly, the evidence is as follows : Colour-banding is a marked feature of the Arran Carboniferous. Red, purple, lilac, pink, and variegated layers alternate with others that are substantially white. The colour distribution is exactly such as would result from oxidation in situ of the iron carbonate and sulphides characteristic of the continuation of the Arran zones elsewhere in Scotland. It is *not* what might be expected as a result of staining by percolating solutions, for all the relatively impermiable clays and shales are affected, while many of the intervening porous sandstones are practically white. The necessity for connecting the colouration directly or indirectly with the New Red Sandstone is equally cogent. The Arran development of the Carboniferous is very thin, and the zones that are reddened in Arran are much closer to the New Red Sandstone than are their grey or black counterparts in Ayrshire—where the most useful comparison can be made. Gunn's measurement from the base of the New Red Sandstone down to the base of the Scottish Carboniferous Limestone Series at Corrie in Arran is only 575 feet. In central Ayrshire the corresponding thickness is 2,050 feet. At Corrie, secondary reddening certainly continues well below the base of the Carboniferous limestone; whereas, in central Ayrshire, reddening, whether primary or secondary, ceases (very approximately) 850 feet above that level. All admit that the climatic conditions of New Red Sandstone times eliminated vegetation and thus permitted oxidation of such iron as was available at the surface. The Arran evidence shows that the influence of the climate extended for hundreds of feet underground. Drought, aided by drainage facilities, must have admitted air far down into the parched Carboniferous substratum of the New Red Sandstone desert, and, when occasional water penetrated, it was water free from organic pollution.[1] It follows as a corollary that the New Red Sandstone itself, growing eventually into a deposit thousands of feet thick, must have blanketed the Carboniferous and provided a protection from climatic colouring rather than a source of stain.

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[1] W. Gunn, " The Geology of North Arran, etc." : *Mem. Geol. Surv.*, 1903.

[2] As so often, Peach's important deduction has remained practically unpublished. It introduced me to the problem, and in large measure provided a solution. If I have been able to improve upon it in any degree, it is because of the ample opportunity provided by a month's holiday at Corrie, where the evidence is most conveniently displayed. The general prevalence of red staining among British Carboniferous rocks was a favourite subject with J. G. Goodchild, " Desert Conditions in Britain " : *Trans. Geol. Soc., Glasgow*, vol. xi, 1898, p. 93. He attributed it to percolation of solutions, from lakes of New Red Sandstone age, see " Desert Conditions in Britain " : *Trans. Geol. Soc. Edinburgh*, vol. vii, 1899, p. 214.

The foregoing remarks can be most conveniently substantiated in the roadside coastal exposures of Corrie village. The sequence according to Gunn's measurements reads as follows:—

	Feet.
New Red Sandstone	—
Coal Measures, with an indeterminate proportion of Millstone Grit	150
Scottish Carboniferous Limestone Series, including representatives of the Upper Limestone, Limestone Coal, and Lower Limestone Groups	425
Calciferous Sandstone Series, with 450 feet of volcanic rocks and 75 feet of cornstone-bearing rocks, the latter probably better referred to the Upper Old Red Sandstone	800

The critical points will now be considered under separate headings.

(1) *Secondary Reddening.*—The reality of secondary reddening in the Corrie section of the Carboniferous is most clearly illustrated among the local representatives of the Lower and Upper Limestone Groups, where marine fossils testify to normal conditions of deposit. The lower group is represented by the 20 foot Corrie Limestone in which beds of limestone (very slightly pink) "are separated by thin partings of reddish shale". Overlying shales and sandstones also show varying tints of red, while thick red shales are seen beneath the limestone in an inland quarry (north of Maol Donn). The Upper Limestone Group includes five or six thin bands of limestone separated by shales and sandstones. The limestones are in this case brick red, and the shales exhibit several shades of the same

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[1] A serious difficulty is furnished by the absence of deep-seated oxidation in the Egyptian Sahara. W. F. Hume in his "Geology of Egypt," *Mem. Surv. Egypt*, vol. i, 1918, p. 152, accepts W. B. Pollard's proof that many Egyptian rocks retain ferrous compounds, which on oxidation give rise to a strictly superficial desert film. The difference is probably connected with the fact that the Egyptian portion of the Sahara is not a *red desert* at all comparable with that which occupied the British area in New Red Sandstone times. To obtain help in this matter, I sent my manuscript to my friend G. W. Grabham. His communication, p. 280, makes it clear that the New Red Sandstone type of desert is not realized in the Sudan, although, perhaps, it is more nearly approached there than at Cairo.

colour. After having reached conviction in the light of these several examples, it is interesting to go over every clay and shale that occurs above the base of the Carboniferous Limestone. Each one is distinctly reddish. If the reddish tint were replaced by grey, or black, the appearance would be that of an ordinary Scottish Carboniferous succession, except that coals are absent both in the Limestone Coal Group and Coal Measures. Although this absence is probably an original peculiarity, there can be little doubt that most of the reddening is secondary.

(2) *Reddening not due to Staining from Above.*—The interbanding of reddened and non-reddened beds has already been cited as evidence against staining by solutions from the New Red Sandstone. White sandstone plays an important part in the Limestone Coal Group, in the middle of the Upper Limestone Group, and in the lower part of the Millstone Grit (and Coal Measure) succession. The upper part of the Millstone Grit (and Coal Measure) outcrop mainly consists of red and mottled clays, red and purplish shales, and occasional sandstone. Their Lanarkian age is defined by included plants, but whether they are Coal Measures or Millstone Grit cannot be decided. The red colour is here so general, that it might seem due to staining from above, were it not that 6 feet of almost white sandstone intervenes below the base of the New Red Sandstone. The relations at the junction of the two systems are so instructive that they deserve special notice (par. 3). First of all, however, attention must be directed to a particularly striking example of selective reddening that occurs well down in the Calciferous Sandstone Series.

A soft bed of sandstone shows through shingle just south of some walled gardens north of the limestone quarry harbour. It is fine grained and rather soft, and is so pale a pink that it is almost white except for an irregular speckling with minute deep red spherical spots. These latter occur about a dozen to the square centimetre, and individually measure roughly 0·5 mm. There can be little hesitation in pronouncing them haematitic pseudomorphs after spherosiderite.

It is certain that the upper part of the Corrie Calciferous Sandstone has undergone the same secondary reddening as the overlying Carboniferous Limestone Series; but it would be unsafe to claim all the red colouration of the Calciferous Sandstone as secondary. There are basalt lavas in the lower part of the Corrie sequence that may have yielded red sedimentary material through weathering—as in Ayrshire. Moreover, Gunn points out a recurrence of cornstone concretions of Upper Old Red Sandstone type in the lower part of the Calciferous (above Carboniferous fossils) some miles north of Corrie, and it is generally admitted that red is a natural climatic colour of part of the series.

(3) *Relations at Contact of Carboniferous and New Red Systems.*—New Red Sandstone may be seen resting on Coal Measure (or Millstone Grit) sandstone on the shore about 200 yards south of Corrie

Hotel. The exposure can be easily found, and the junction located with the utmost precision.

The plane of contact is parallel with the general stratification of the underlying Carboniferous (dune-bedding in the New Red renders comparison impossible in an upward direction). Along it are scattered minute pebbles of vein-quartz and iron-pan, which, mixed with quartz grains, many of them rounded, constitute an apology for a basement conglomerate. Above, comes a great mass of New Red Sandstone, red in colour, dune-bedded,[1] and characterized by abundant layers of wind-rounded quartz grains with diameters of 0·5–1·0 mm. (Many of the quartz grains are smaller, 0·1–0·2 mm., and have escaped any conspicuous degree of rounding.) I think it is universally recognized that these New Red Sandstones at Corrie accumulated as desert dunes, and that their red colouration is an original climatic character.

Below the junction plane comes a very interesting layer, some 6 feet thick, of Carboniferous sandstone. Its base, followed by a little Tertiary sill, is determined by more or less even stratification; but, internally, the bedding of the layer is extraordinarily involved. It is puckered and overfolded, with recumbent folds extending for as much as 4 feet in a horizontal sense. Altogether, its escarpment looks like a picture taken from some modern book on the Alps. The phenomenon is evidently due to plastic flow down a slope of deposition. It is shown in other parts of the Arran Carboniferous, but not in the New Red Sandstone.

Another distinguishing feature of the Carboniferous Sandstone is an absence of anything like the relatively large round grains of the immediately overlying New Red Sandstone; instead, there is a fair proportion of mica flakes, which are particularly abundant in certain darker laminae that enable the eye to follow at a glance the convoluted bedding of the whole. And, then, there is the colour contrast! The bulk of this Carboniferous layer is practically white, with pink and red along the intricately folded darker micaceous laminae—presumably determined by an original slight concentration of iron sulphide or carbonate—and with deep brick red limited to certain self-contained masses that form the most striking feature of the exposure. Of staining, there is almost certain evidence; but it only extends for about an inch or so down from the New Red Sandstone and for a similar short distance outwards from the red masses.

The red masses are fairly numerous. Nine are exposed in the 50 yards of the narrow foreshore outcrop. In size they vary considerably, and the largest measures 10 by 2½ feet, with a depth of 1 foot. Their boundaries, apart from trivial extension by what appears to be staining, are very definite and smooth; and yet the masses are not in any sense boulders: they consist of the same somewhat micaceous sandstone as embeds them—only they have a deep red ferruginous matrix. Even the contorted laminae run continuously from the white sandstone, through the red sandstone, and out again. It seems almost certain that the red masses formed originally as concretions with a base of ferriferous carbonate, and that they owe their present condition to oxidation during New Red Sandstone times.

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[1] J. W. Gregory seems to have first described the dune-bedding and wind-rounded grains of the lower part of the New Red Sandstone of Arran. "The Permian and Triassic Rocks of Arran": *Trans. Geol. Soc. Glasgow*, vol. xv, 1914, p. 183.

Note on Red Colouration under Climatic Influence in the Sudan.

By G. W. Grabham, M.A.

THE following remarks have been suggested by the perusal of Mr. E. B. Bailey's draft of his paper on the "Subterranean Penetration by a Desert Climate".

Desert Deposits.

The desert is essentially a region of erosion or deflation and conditions are entirely against the accumulation of deposits. Referring to the Sahara, a great deal of sand and dust is produced which accumulates where it is brought to rest either by water or vegetation in the surrounding regions.

Climate and Colouration.

The climate of the north is much cooler than that of the southern border of the Sahara. Along the Nile, between Aswan and Halfa, desert sand pours from the plateau and fills valleys and wind shadows. That sand is of a distinct orange colour, much more so, I think, than sand seen in the desert near Cairo.

In Kordofan, where there is now a rainfall of about 12 inches or more, there are extensive accumulations of millet seed sand which were doubtless formed when the desert extended farther south. The desert is now too far north for desert sands to penetrate so far beyond its border. The surface portion of the sand is a decided red colour and with the moisture of the rainy season the full red of the soil would compare with that of Devonshire. The evidence of many wells shows that the colouration is limited to the surface, and, without giving a definite figure, it may be stated that it does not extend more than 20 feet below the surface. The accumulations of blown sand are much deeper.

The orange-coloured sand prevails in the desert south of Wadi Halfa, but here, as, for instance, at No. 4 Station on the railway, it is found to cover a deep red sandy subsoil. The neighbouring crystalline rocks which are deeply decomposed are not stained.

In the Nubian Sandstone of the region between Halfa and Khartoum there is sometimes a reddened crust limited to a depth of perhaps 10 feet below the original surface. Walther, who noticed it first, regarded it as a consequence of a definite climate which he referred to as a " Red Climate ". My view, after travels in the more tropical parts of the Sudan, is that the reddened crust of the sandstone is a result of the former northward extension of the lateritic climate which was a good deal more rainy than the present.

SEQUENCE OF EVENTS IN THE SUDAN.

We may picture the desert border formerly swinging southwards and allowing the sands to accumulate in Kordofan. Subsequently it must have swung back and the Red Climate prevailed, leading to formation of laterite and the staining of the Kordofan soils. Its influence extended northwards far enough to allow the desert surface sands, at least as far north as Aswan, to assume a distinct orange tint. Its effects have not penetrated deeply. Even farther south than Kordofan, I have never met with evidence of the deep penetration of the red colouration. In this connexion it is interesting to note Walther's view[1] that the lateritic type of climate does not now exist on our planet. He considers that it belongs to a time when there were quantities of moisture in the atmosphere and heavy precipitations alternated with increased heat of the sun, which quickly dispersed the moisture.

ORIGIN OF THE COLOURATION.

Whether the red colouration is due to the oxidation of iron already existing or whether additional iron has been carried in by solution presents a further problem. Desert sands are usually fairly clean and it is difficult to see how the surface sand at No. 4 could become reddened to the same degree as the subsoil without the agency of circulating solutions. Where the underlying rocks are ferriferous and have decomposed, we can regard them as the source of the additional iron. In Kordofan, on the other hand, we have Red Sands resting on comparatively white sands. Possibly the small iron content of the deeper-seated sands was drawn up to colour the surface layers. Otherwise, it is difficult to see whence the iron could have been derived.

COLOURING AND BLEACHING.

If rocks are fairly readily stained under certain climatic conditions, is it not probable that at least some of the staining may be obliterated under other conditions ? We might expect both the staining and the bleaching to be selective. It is easy to imagine that clays and shales may take up the colouring more readily and subsequently retain it more firmly than sandstones. Thus the bed of white sandstone near the top of the Carboniferous at Corrie[2] may never have been deeply stained, and, providing a ready passage for circulating water, may subsequently have been easily bleached.

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[1] Abstract, " Desert Formation in Present and Past Times," Leiningen, *Proc. Inst. Sc᷊. Soil Science,* vol. i, p. 59, 1925.

[[2] From my point of view it should be remembered by the reader of the next two paragraphs that at Corrie well over a thousand feet of red sandstone of New Red Sandstone age rest upon six feet of white sandstone of Carboniferous age.—E. B. B.]

Just as the Carboniferous rocks have been stained subsequently, it seems quite possible that the staining which is so characteristic of the New Red may not have been contemporaneous with its accumulation. Such a contention is so novel that it will provoke a deal of criticism.

TORQUAY.

In the neighbourhood of Torquay, New Red Sandstones rest on Devonian limestones, grits, and slates and the extent and nature of the staining would certainly repay study.

REVIEW.

THE PETROLOGY OF THE IGNEOUS ROCKS. By F. H. HATCH and A. K. WELLS. Eighth edition. pp. xxiv + 566, with 144 figures. London: George Allen and Unwin, 1926. Price 15*s*. net.

IT is with great pleasure that we welcome the appearance of the eighth edition of this well-known textbook, in which Dr. Hatch has had the advantage of the collaboration of Dr. A. K. Wells. The seventh edition appeared in 1914, and the book had long been out of print. It has now increased in size by about 100 pages of text, in addition to greatly expanded and very useful index-matter under three separate headings, an increase which is amply justified by the advances made in petrology in the last twelve years. It is highly satisfactory to find, however, that the important changes made by the authors are in the direction of simplification rather than of complication of the subject. Petrology as much as, if not more than any branch of science, has suffered in the past from an undue complexity of nomenclature, which has imported into it a quite unnecessary amount of difficulty, and has most undoubtedly exercised a deterrent effect on students. In this book the number of essential names is reduced to a minimum, and most of the cacophonous horrors which have recently disfigured the subject are here relegated to a special "Index of Names of Igneous Rocks", which is in effect an *Index Expurgatorius*. Where it is considered that a name is unnecessary a short definition is given in this index of the character of the rock, and the name itself does not appear in the text. The authors support strongly the recommendations of the Committee on Petrographical Nomenclature that sat a few years ago, even expressing in the preface a regret that the report of this committee did not go far enough. In this view most petrographers will undoubtedly concur.

Among the most interesting new features of this edition are sections on the consolidation of igneous magmas, and on the work of the Geophysical Laboratory at Washington. While some of the higher flights of the physico-chemical study of petrogenesis on experimental lines are too complicated and specialized for elementary students of geology, it is certainly well that even beginners should be introduced at an early stage to some of the simpler and more fundamental principles on which modern ideas of the formation of igneous rocks are based, since this undoubtedly renders the whole thing much more intelligible, as it provides a reason based on physical chemistry for the mineral constitution or glassy composition of rocks and for the resulting textures and structures. Without such a basis the whole subject is merely empirical memory work, a collection of disconnected facts. The chapters on consolidation of magmas and on the principles of classification are well abreast of the most recent developments of their subjects and are worthy of very careful study. The authors have wisely retained the general system of classification evolved by Dr. Hatch for the fifth edition (1909) which has been found so satisfactory in practice; though it would be possible to pick holes in it on various grounds, no other system is actually so useful or so easy to understand and apply in descriptive work, since it makes use of both chemical and physical characters. The section on metamorphic changes (in the wider sense) in the igneous rocks has been considerably enlarged, and a very good account is given of pneumatolytic and other allied late-magmatic changes such as albitization, analcitization, and the large group of alterations that affect so many igneous rocks both intrusive and extrusive in relation to the formation of ore-deposits (propylitization and so forth). Many of these are of considerable economic importance, but are as a rule inadequately treated in text-books of petrology.

The last section of the book, on the igneous rocks of the British Isles, has been entirely rewritten on a new plan. Instead of a petrographical arrangement, the treatment is now historical, with special stress on cycles of activity: this is a great improvement, as it allows of a genetic treatment. It is obviously most desirable that the petrography of a region should be clearly linked up with the general geological history and especially with the various sets of earth-movements that have controlled this history. This the authors have now done. While there is perhaps a little more detail in some parts than is required by elementary students, the whole cannot fail to be of the greatest value to all geologists, as it incorporates all or nearly all of the latest results, including publications so recent as the Survey Memoirs on Mull and the address of the President of the Geological Society for 1925. In this section the authors have exercised a wise and cautious policy of suspended judgment in certain cases where the interpretation of evidence is still a matter of uncertainty, the only truly scientific attitude.

In the introductory paragraphs to this section, dealing with petrographical provinces, much stress is laid on Daly's valuable data as to the actual and relative abundance in nature of alkaline and calc-alkaline provinces, thus emphasizing the damage that has been done to petrology by the cultivation of "interesting" but rare rock-types. Most of these are alkaline, and they occupy a quite disproportionate amount of space in the literature, since Daly has shown that alkaline types amount to less than 1 per cent of the known total. It cannot be too strongly emphasized that the dominant rock-types of the world are acid intrusives (granites in the wide sense) and basic lavas. This fact is of fundamental importance in geotectonic theory and rests on a sound basis of observation.

REPORTS AND PROCEEDINGS.

GLASGOW GEOLOGICAL SOCIETY.

11*th March*, 1926.

Dr. G. W. Tyrrell, University of Glasgow, delivered the third and concluding part of his Presidential Address on "Igneous Action and Earth Movement in Scotland and Scandinavia". A synopsis of the whole address is here given.

The first part dealt with the Caledonian Revolution and the events which led up to it in the Lower Palaeozoic era. The geological cycle was analysed, and the subdivision of it given by Sonder, namely into four phases, the orogenic or emergence phase, the continental phase, the geosynclinal or submergence phase, and the fluctuation or transgression phase, was adopted as its best available expression. The geological cycle was correlated with the thermal cycle of Joly, which proceeds in the universal basaltic substratum underlying the crust. The orogenic phase of Sonder corresponds with the solidification and contraction phase of the basaltic layer, resulting in a period of crustal compression; the remaining three phases of the geological cycle, representing a period about three times as long as the orogenic phase, corresponds to the fusion period of the Joly cycle, with the resultant crustal tension.

By a general survey of igneous activity, with particular application to the abundant records in Scotland and Scandinavia, it was then sought to establish an igneous cycle running parallel to the geological and thermal cycles. It was found that granodiorite-andesite kindreds and anorthosite-charnockite kindreds were characteristic of the orogenic phase; whilst basalt floods and the subordinate alkaline kindreds appeared during the long succeeding part of the cycle, in which crustal tension predominated, and the fusion of the basaltic substratum was proceeding. The spilitic kindred was characteristic of the geosynclinal phase, and was consequently often involved in the ensuing orogeny on the geosynclinal sites, and converted into the familiar "green rocks" of fold-mountain regions.

Dr. Tyrrell then analysed the diastrophic and igneous cycles of the Lower Palaeozoic in Scotland and Scandinavia. The Torridonian continental phase exhibited no igneous activity in Scotland, but the corresponding rocks in Scandinavia include amygdaloidal basalts and quartz-dolerite. In America the corresponding period (Keweenawan) saw one of the greatest known basaltic floods, and two of the largest basic intrusions (Duluth and Sudbury) in the world. The geosynclinal and transgression phases are represented in Scottish igneous history (and also in Norway) by outpourings of soda-rich spilitic lavas, and by albite-rich intrusions, with green rocks and serpentine. In the transgression phase, however, igneous activity is at a minimum. In the final upheaval of the Caledonian Revolution there appears to have been two paroxysms of igneous activity, separated by earth movements. This accounts for the foliation of some of the earlier intrusions, and the absence of foliation in the later stages. Granodiorite and andesite are the main rock types erupted in Scotland during this orogenic period. In Scandinavia anorthositic kindreds appeared in the deep-seated portions of the Caledonian fold mountains, as well as granodioritic rocks.

The second part of the address, entitled " The Aftermath of the Caledonian Revolution ", dealt mainly with a detailed comparison of the Carboniferous petrographical province of Scotland with the Devonian (?) province of Norway. The tectonic history of the period was the breaking up of the Caledonian region, with the production of a fracture-mosaic, and the formation of two major rift valleys, the Midland Valley of Scotland and the Kristiania region of Norway. The correspondence between the tectonic structures and igneous events of these two regions was shown. The main differences were the absence of plutonic rocks in the Scottish field, probably due to the fact that the younger sediments are largely preserved on the floor of the rift, and that erosion has not yet bitten down deeply enough to expose the roots of the volcanoes ; and the abundance of analcite in the Scottish assemblage as compared with its paucity in the Kristiania province. The view was hazarded that this was due to the wet condition of the mainly younger sediments, into which the Scottish rocks were injected.

Part III of the address dealt with the Cainozoic igneous episodes in the west of the British area, and the North Atlantic region in general. An analysis of the general character and sequence of Cainozoic igneous activity, based on the facts disclosed in the great Survey Memoirs on Skye and Mull, aided by the author's recent work on Arran, shows that a phase of regional activity, resulting in the outflow of vast basalt floods, was the first effect of the revival of igneous action in the North Atlantic. This was followed by a local phase, in which the igneous activity was restricted to nine or ten centres in the western part of the British Isles. This local phase was attended by the development of a Hawaiian type of shield volcano at each centre, the outpouring of a somewhat different type of basalt to the plateau type, and the intrusion of large plutonic masses at the roots of the volcanoes, with one or two cycles of change from basic to acid composition. In this phase great explosive activity occurred connected with the intrusion of acid magma, and the peculiar phenomena of cone-sheets and ring-dykes reached their maximum development. At the end of the igneous episode, another regional phase reached its culmination, namely the intrusion of great dyke-swarms centering about the local vents, but directed north-west to south-east in a system of tension fissures. The opening of tensional fissures, and dyke injection, had gone on at intervals during practically the whole period of igneous activity, but reached its maximum development towards the end. The whole of the igneous cycle of the Kainozoic in the British area was thus connected with the development of tensional stresses, and is therefore correlated with the fusion part of the Joly cycle. Attention was drawn to the eruption of basalt floods in comparatively recent times on the western edges of land masses. It was suggested that this fact was to be correlated with the relative instability, height, and liability to earth movements, fiord formation, etc., of the western sides of continents as compared with other parts; and, according to Holmes's recent diagram of a typical continent (GEOL. MAG., Dec., 1925, p. 532), the weakest and thinnest part of the solid crust lies just off the western edge of the land mass.

GEOLOGISTS' ASSOCIATION.

Friday, 7th May, 1926.

"The Petrology of the Shap Granite." By D. R. Grantham, Ph.D., A.R.S.M., A.R.C.S., B.Sc.

Field evidence for the Shap Granite being a composite intrusion. Mineral composition of the varieties, and the criteria distinguishing them. Pneumatolysis and mineralization. Petrological description and analyses of the main types: (1) Inclusions (*a*) of sedimentary origin; a calc-silicate hornfels derived from the Upper Coniston Limestone, its stages of alteration with analyses of core, margin and enveloping granite: (*b*) of igneous origin; metamorphosed Borrowdale Volcanic rocks, definite granitic inclusions, and types intermediate between these. (2) Stage I granite. (3) Stage II granite. (4) Stage III granite. (5) A hornblende granite. Variation diagram.

The existence of extensive mechanical disintegration of included masses and fragments of country rocks and the probability of concomitant chemical assimilation.

"Notes on the Shoshone Valley, Yellowstone National Park, U.S.A." By George W. Young, F.G.S., F.Z.S.

The Shoshone River rises in the Absaroka Mountains, which flank the eastern side of the Yellowstone Park plateau. They consist of a great series of Tertiary volcanic breccias, lavas, and basalts, over 5,000 feet in thickness, and rise to heights of 10,000 and 12,000 feet above sea level. The Shoshone Valley is deep and in places precipitous, and weathering has carved the breccias into remarkable, and often grotesque, forms. Basaltic dykes are numerous.

After leaving the Absarokas and traversing about 15 miles of bare open country, one reaches Rattlesnake Ridge, a sharp anticline of Mesozoic and Palaeozoic rocks, with a core of Archaean. Through this the river has cut a very deep and narrow gorge, across which the Shoshone dam has been built—328 feet in height, the highest but one in the world. Beyond the Ridge the country is flatter, and continues so for many miles.

YORKSHIRE GEOLOGICAL SOCIETY.

13*th March*, 1926.

" The Petrography of the Carstone and Associated Beds." By H. C. Versey, M.Sc., F.G.S., and C. Carter, M.Sc.

The stratigraphical relations of the Carstone from Kirkby Underdale in Yorkshire to Snettisham in Norfolk were described and comparisons made with the Speeton series below and the Red Chalk above. The Carstone is found to be made up chiefly of sandstone pebbles with some detrital phosphate and glauconite and occasional igneous fragments set in a cement which varies from calcite through ferruginous clay to chamosite. The heavy minerals include zircon, kyanite, garnet, rutile, staurolite, tourmaline, hornblende, epidote, magnetite, with topaz, diopside and spinel more sparingly found. Kyanite, staurolite and epidote diminish in amount northwards, while garnet and rutile show diminution in the reverse direction.

The Red Chalk shows an entirely similar suite of minerals and there is no line that can be drawn between the two formations.

The succession of strata from the Sandringham Sands to the Carstone shows a general increase in the percentage of metamorphic minerals.

It is suggested that the main material of the Carstone came from the south where Jurassic and Lower Cretaceous rocks were undergoing erosion. Some detritus came from the north, but the differences between the clays of Speeton and the equivalent beds in Lincolnshire almost disappeared in Carstone times.

The bed represents very slow, sometimes interrupted sedimentation on a fairly uniform sea-floor with very little current action. Its great petrographical similarity to the Red Chalk confirms the assignment of the Carstone to the Upper Cretaceous.

" Yeovilian Ammonites in the Inland Area of the Yorkshire Moors." By W. E. F. Macmillan.

Sections are described in Great Fryup, Little Fryup and Danby Dale where an ammonite fauna occurs comparable with that of Blea Wyke. The forms include species belonging to the following genera :—*Phlyseogrammoceras, Grammoceras, Hudlestonia.*

" Notes on the Drainage of the Foothills from Masham to Wetherby." By W. H. Young, M.A.

The area under discussion marks the point where the Tees ice and Ure ice met. It is suggested that the southerly deflection of the Ure tributaries was a result of the more powerful Tees ice. The special case of Hutts Gill, near Grewelthorpe, is compared with the "Trough" described in the East Rongbuk Glacier on Everest. The author attributes the northerly deflection of these tributaries either to a very late movement of the Harrogate anticline or to the lingering of the Aire ice after the retreat of the other valley glaciers.

Mr. H. B. Maufe, B.A., F.G.S., gave a lecture entitled :—"Notes on the Geology of Southern Rhodesia."

ANNOUNCEMENTS AND INQUIRIES.

The name *Crania* used for a fossil arthropod in our paper entitled "On some Arthropod Remains from the Rhynie Chert" (GEOLOGICAL MAGAZINE, February, 1926, p. 70) is preoccupied by (*Crania*, Retz., 1781). We therefore propose the name *Heterocrania* for the arthropod from the Rhynie Chert.

S. HIRST,
S. MAULIK.

Postscript to Seward and Sahni, "Indian Gondwana Plants: A Revision" (*Palaeontologia Indica*, 1920, vol. vii, Mem. No. 1, p. 14).

In describing the Lower Gondwana specimen to which the late Professor Zeiller had given the name *Araucarites Oldhami* we had originally suggested what was intended to be a new generic name, *Morania*, coined after the locality (Moran River) where the fossil was discovered. We now find, however, that an identical name had previously been applied by Dr. C. D. Walcott [1] to an Alga-like plant from the Burgess Shale of British Columbia. It is therefore necessary that a fresh designation be adopted for the Indian specimen. For this we now suggest the new generic name *Moranocladus*; the type-specimen would thus be known as *Moranocladus Oldhami* (Zeill.).

A. C. S.
B. S.

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[1] C. D. Walcott: "Cambrian Geology and Palaeontology," *Smithsonian Miscellaneous Collections*, vol. 67, No. 5, Middle Cambrian Algae, p. 225, 1919.